JANUARY 1960
No. 243

ASTM Bulletin

American Society for Testing Materials

RESEARCH AND STANDARDS FOR MATERIALS

This is a single fiber derived from the wood of a Douglas fir.

Latin name: Pseudotsuga menziesii. Dimensions: spectacularly minute. Length: 0.165". Cross-section area: 0.318×10^{-6} sq. in. It makes a common straight pin look like a flag pole in comparison.

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ASTM BULLETIN

Research and Standards for Materials

Number 243 January 1960

1959—An Active Year for ASTM

Few areas of industry left untouched by busy hands of ASTM technical committees

THE 1960's ARE upon, us and in looking back over the accomplishments and adventures of 1959 we may detect a glimmer of what may lie ahead. So many things happened in ASTM in 1959—with two major national meetings, one in June in Atlantic City and one in October in San Francisco, as well as the hundreds of individual committee meetings held throughout the year—one may easily be overwhelmed in attempting to take an over-all look at the whole. ASTM activities provide the kind of variety that interests different people for different reasons: some from a purely scientific point of view, some because of the helpful engineering information, some because of the bread-and-butter specification and test work that smooths the way for buying and selling materials. To see what ASTM meant in 1959 to different groups of people and different industry segments, let us examine the year 1959 in these terms.

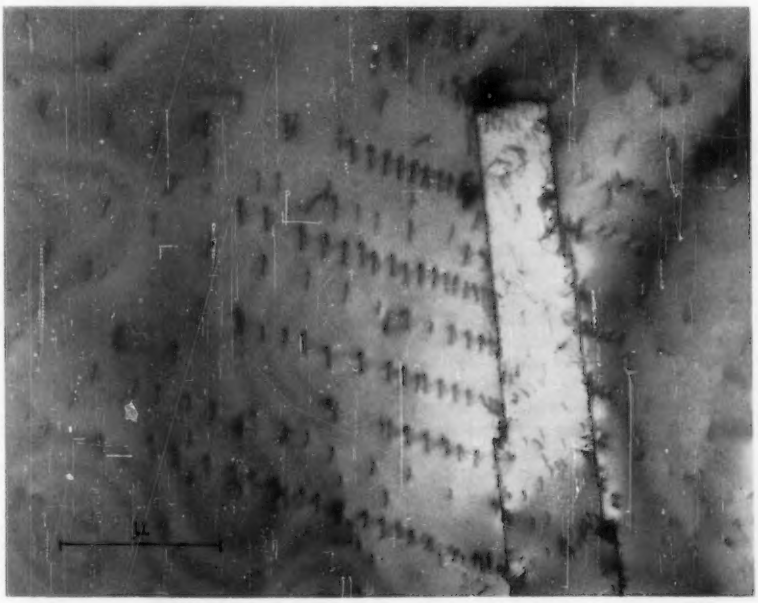
▶ ASTM in Highway and Airfield Construction

Supplementing and laying a baseline for standardization work in committees dealing with cement and concrete, road and paving materials, and load-bearing properties of soils are a number of symposia held last year. Design of bituminous paving mixtures and related test methods were discussed in one symposium. Another covered the significance of tests and properties of bituminous binders. Both of these symposia, published together as *STP-252*, provide information of considerable value in highway work. Also at the Annual Meeting were two symposia dealing with soils, being published together as *STP 254*.

Symposia were held at the October meeting at San Francisco covering admixtures in concrete and also road and paving materials.

Other activities of the Society of special interest to those in highway and airfield construction include the standardization work in Committees C-4 and C-13 covering clay and concrete pipe, used extensively for drainage purposes.

Skidding is a recurring hazard on highways and airport runways. An international conference on skid resistance held late in 1958 revealed that there are no standard means for evaluating the resistance to skidding of the materials used in highway and runway surfaces, or for tire materials. As a result, the Society has established a new Committee E-16 on Skid Resistance. Three of the present ASTM committees have a special interest: C-9 on Concrete, D-4 on Road and Paving Materials, and D-11 on Rubber.



CLUE TO METALS BEHAVIOR?

Dislocation pile-up at a twin boundary in stainless-steel foil extended 2 per cent.

Review of the ASTM Year—1959

▶ ASTM in Housing and Building

In addition to the many materials that are the subjects of ASTM standards—steel, concrete, wood, masonry, paint, plastics, adhesives, thermal insulation, gypsum products, acoustical materials, and many others—there are two committees whose work is directed principally toward housing and building, particularly building codes. Committee E-5 on Fire Tests has established the standards for fire rating of materials for code purposes and is also concerned with evaluation of materials as to relative flammability. Committee E-6 on Methods of Testing Building Constructions, early in 1959, sponsored a symposium on testing window assemblies recently published as *STP 251*. The committee has also been interested in the problem of slab-on-ground construction, particularly the matter of protection against moisture penetration. At the request of the Federal Housing Administration, the committee is preparing a method for evaluating the moisture-barrier material that is used under concrete slabs placed directly in the ground.

Committee C-20 on Acoustical Materials has completed a research project underwritten by the Acoustic Materials Assn. to study flame-spread properties of these materials using the ASTM tunnel test (E 119).

The efficiency of timber as a structural material is often limited by the means for holding it together. With the development of modern adhesives, new types of wood construction are possible. Problems relating to scarf joints in laminated wood beams and screw-holding ability of western woods are subjects discussed at a two-session symposium on wood in building constructions held at the West Coast Meeting.

Other sessions on testing building constructions and on masonry and bituminous waterproofing materials at the West Coast Meeting provide additional information for application of these materials in building construction.

With the increase in curtain-wall type of construction, where large prefabricated panels are assembled on the site, the problems of sealing the joints between these panels has occupied much attention. Early in 1959, an industry group proposed a specification for joint sealants to the American Standards Assn. Growing out of meetings with ASA and industrial companies was the establishment in September of the new ASTM Committee C-24 on Joint Sealants. Materials under the cognizance of the committee cover caulking and glazing compounds as well as preformed shapes used in building construction.

▶ ASTM in Nucleonics

Among the subjects considered both in committee discussions and in symposia are the use of radioisotopes in testing materials, radiation effects on all kinds of materials, and problems of radiation shielding. Both at the Annual Meeting and at the West Coast Meeting there were symposia on these subjects. The Society's Special Administrative Committee on Nuclear Problems conducted two nuclear forums during 1959 at these national meetings. Participating were members and officers of the technical committees and others interested in nuclear reactor design.

Typical activities of the Society toward standards for radiation effects and measurements are those to modify existing specifications for corrosion-resistant metals, where appropriate, to apply them to reactor construction, standards for industrial water of high purity for reactor use, and methods covering both radiation effects and dosimetry for exposure studies of electrical insulation and plastics. Committee C-9 on Concrete has a subcommittee concerned with the use of concrete for radiation shielding. Publications of the Society in the radiation field are extensive.

Nuclear graphite is the subject of a new subgroup recently established in the ceramics committee, C-21.

▶ ASTM in Industrial Chemicals and Chemical Construction

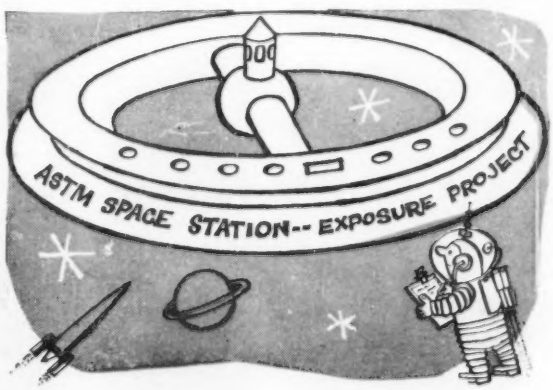
Materials used in chemical construction include certain corrosion-resistant metals for which specifications have been written with this application in mind. Committee C-3 on Chemical-Resistant Mortars is concerned with application of this type of material in chemical construction. The committee on clay pipe, also mindful of the use of this material in environments where there is exposure to acid, alkali, scour wastes, etc., has established standards for pipe for these applications.

Plastic pipe is the subject of study and standardization in the plastics committee. This material is widely used in the chemical and petroleum industry because of its resistance to certain types of chemicals.

In the field of industrial chemicals, the Society last year completed the organization of a committee on analysis and testing of industrial chemicals with cooperation of the Manufacturing Chemists' Assn. in supplying the secretariat. This committee will have a dual function: one to develop test methods for chemicals not now covered in the Society and the other to coordinate and establish chemical analytical methods useful to the chemical industry. The work of this committee will supplement the Society's already extensive work on industrial chemicals in committees dealing with such materials as petroleum products, paints, engine antifreezes, soaps and detergents, and aromatic hydrocarbons.

▶ ASTM in Aerospace

While ASTM is not yet ready to establish an exposure site in a location out of this world, this may not be too long in coming, since more and more materials, in the form of satellites and space probes, are being thrust beyond the earth's atmosphere. Many of the activities of ASTM are of special interest to the aerospace industry. Some of the problems of flight within the atmosphere were discussed at the symposium on fatigue of aircraft structures at the West Coast Meeting. Consideration was also given to problems of fatigue in missile and space-flight structures which, in contrast to manned aircraft, are subjected to a relatively small number of load cycles throughout their lives.



Thermal ablation was the subject of another West Coast symposium which

established a base line for standardization of ablation tests in Committee D-20 on Plastics.

The work of ASTM Committee C-19 on Structural Sandwich Constructions as well as that of the ASTM-ASME Joint Committee on Effects of Temperature on the Properties of Metals are of special interest to designers of aircraft and space vehicles.

At the West Coast Meeting, the symposium on nondestructive testing in the missile industry brought out the importance of stringent inspection of materials used in space vehicles. Both radiography and ultrasonic methods are used to detect flaws and incipient flaws in structures so that the chance of failure from such causes will be minimized. Ultrasonic inspection is of particular value in evaluating adhesive bonds in structural sandwich constructions, widely used in aircraft and space vehicles.

▶ ASTM in Education

In an Annual Meeting symposium, sponsored jointly by ASTM and the American Society for Engineering Education, prominent educators and industrialists took a long, hard look at the teaching of materials in colleges of engineering. The technological revolution that was sparked by World War II, and which had been growing in intensity ever since, has made imperative a critical analysis of present-day teaching methods and curricula.

A recurring theme at the education symposium was that the trend toward greater science-orientation in engineering school curricula, with increasing emphasis on fundamentals, is a good one, and should be continued. Too often, today, one finds our empirical knowledge of materials inadequate to cope with the stringent demands being made of them. Only a more basic knowledge of the source of engineering properties of materials will enable us to break the log jams that exist at many points on our technological frontier.

This symposium will be published soon by the Society as *STP 263*.

▶ ASTM in Electronics

The very specialized materials used for cathodes and other interior parts of electron tubes are standardized by Committee F-1 on Materials for Electron Tubes and Semiconductor Devices. The committee has established several standards for semiconductor materials.

Several other committees in the Society contribute to solutions of problems in the electronics industry. These activities were described in a session at the West Coast Meeting, where electronics work in Committees A-6 on Magnetic Properties, C-21 on Ceramics, D-9 on Electrical Insulating Materials, and F-1 on Tube Materials were described.

The Society will establish a new committee on electronic ceramics with a nucleus of members from the Electronics Division of the American Ceramics Society.

▶ ASTM in Engineering and Scientific Data

The Society has many continuing projects to publish and make available data for the analyst, such as the data on infrared spectra and X-ray diffraction. For the design engineer and code authorities, there are extensive tabular and graphical data on properties of metals over a wide temperature range. Also, the Society publishes extensive data on the variation with temperature of vicosity and density of hydrocarbons. This work is being extended by the new committee on industrial chemicals to cover chemical products generally.

▶ ASTM Abroad

In the decade just passed, there has been great interest and rapid growth in the field of international standardization both through the International Organization for Standardization and its electrical affiliate, the International Electrotechnical Commission. ASTM is interested in or participates in twenty-five ISO committees and four IEC committees. In some of these, the ASTM committee has been assigned the responsibility of providing the USA viewpoint in the international work in which the American Standards Assn. is the USA member body. It also participates in other international activities.

In addition to participation in international groups, it should be mentioned that many of the ASTM committees have participating members abroad. While it is not feasible for such members to attend meetings regularly, they do participate by correspondence in voting on letter ballots or otherwise contributing to the work of the committee.

The Society has many members abroad, as a glance at the geographic distribution of the members in the Year Book will show. There are ASTM members in such far-off places as: Australia, Belgian Congo, Brazil, Burma, Czechoslovakia, Egypt, New Zealand, Southern Rhodesia, Tasmania, and Venezuela.

Many ASTM publications find their way abroad; the Society's business office is well acquainted with the problems of dollar exchange with foreign currencies and the length of time it takes to ship a book by boat or by air to far corners of the earth.

Perhaps the time is not too distant when the first colony will be established on the moon. One feels that shortly thereafter there will be at least one ASTM member there.

Research and Standards Highlights

Metals

• FRACTURE TESTS FOR SHEET MATERIALS

As the result of a suggestion from the Department of Defense, a group of experts was appointed as a Special ASTM Committee on Fracture Testing of High-Strength Sheet Materials. After five meetings during 1959, the committee is publishing its report in two installments, the first of which appears in this issue of the ASTM BULLETIN, beginning on page 29. The second installment will appear in the February issue. With this report, the committee solicits comments from industry. Comments from interested persons will be helpful to the committee in developing ASTM test methods.

• STEEL (A-1)

Following the acceptance of the specification for high-strength bars for concrete reinforcement (A 431) late in 1958, Committee A-1 issued a companion specification (A 432) covering deformed concrete reinforcement bars with 60,000-psi minimum yield point. Also for structural application the Society approved a specification for high-strength structural steel (A 440) covering a yield strength of 50,000 psi for thicknesses up to $\frac{3}{4}$ in. Further work is continuing on additional specifications to cover thicknesses up to 1 in. with the same yield strength.

Early in 1958, the Society was asked by the Boiler and Pressure Vessel Committee of ASME to set minimum carbon limitations for the regular 300 series of austenitic steels. Since this was a problem common to specifications written by both Committees A-1 on Steel and A-10 on Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys a joint group was established. The report of this group was forwarded to Committees A-1 and A-10 for action early in January, 1959. The 1959 revisions in Specifications A 213, A 249, A 271, A 312, A 376, and A 430, are the first actions as a result of the joint task group report. New grades identified by the suffix "H" are added to the specifications, with

chemical compositions slightly different from the regular 300 series. Solution-treating temperatures are specified for the new grades.

Transition temperatures of steel products are appearing in specification requirements. Revised tables of mechanical requirements are being considered for forged turbine and turbine generator rotors and shafts (A 292 and A 293), including specified transition temperatures. This necessitates standard methods for determining transition temperature. A task group is considering such a method utilizing the V-notch Charpy impact test. Also, specifications for carbon steel plates with improved transition temperature will be patterned after a proposed case of the ASME Boiler and Pressure Vessel Code.

Subcommittee XIII on Specifications for Nuclear Reactor Structural Steels has agreed to add supplementary requirements to the existing specifications for corrosion-resistant steels to cover nuclear applications. When it appears that such supplementary requirements have become too voluminous, separate specifications for particular applications will be written.

● CAST IRON (A-3)

In the field of cast iron, intensive work has been done on the preparation of recommendations for the adoption of new short test bars for tension testing. These new bars will replace the present long (transverse) test bars and are being incorporated into a revision of specifications A 48. The switch from long to short bars breaks a long-standing tradition in testing cast iron.

● FERRO ALLOYS (A-9)

The specifications for ferro-molybdenum (A 132) were revised during 1959. Changes were inaugurated to distinguish the grades by carbon contents for government stockpiling. Grade A previously had been expressed only as a maximum and according to literal interpretation would have included the new Grade B.

● SUPER-STRENGTH ALLOYS (A-10)

A popular publication in the metals field is the Compilation of Chemical Compositions and Rupture Strengths of Super-Strength Alloys (*STP 170-A*). This publication, sponsored by Committee A-10, is kept up to date through periodic revisions. Such a project is now in progress and will be completed early in 1960.

● CORROSION OF IRON AND STEEL (A-5)

Two new atmospheric exposure programs were authorized. One will test the effects of continuous dip as against individually dipped corrugated roofing sheets; aluminum-coated roofing sheets will also be included. The second program will test aluminum-coated wire in various forms, such as farm-field fence, barbed wire, and strand.

Specifications being developed include those for two types of aluminum-coated sheet, galvanized culvert sheet, and galvanized sheets in structural quality. New work includes methods for determining the porosity and uniformity of aluminum coating on steel, and specifications for copper-covered guy strand, flat armored tape, and aluminum-coated wire.

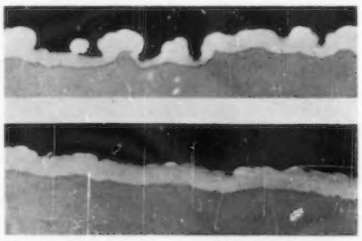
● CORROSION OF NON-FERROUS METALS (B-3)

A new program to evaluate the relative corrosivity of 29 ASTM and other test sites, as well as sites located in Canada, was approved. This study will amplify the information obtained from the 1948 corrosivity study.

● ELECTRODEPOSITED COATINGS (B-8)

The committee has enlarged its activities to include anodized coatings. A new program has been authorized to gather further data on the comparative performance of commercial and heavier chromium-nickel coatings on steel in order to determine which system will lead to improved performance.

Atmospheric exposure specimens are being prepared to determine the performance of decorative chromium-nickel coatings on aluminum alloys.



TWO DEGREES OF UNIFORMITY OF ELECTROPLATED ZINC COATING ON STEEL

● NON-FERROUS METALS (B-2)

The Subcommittee on Miscellaneous Refined Metals and Alloys has established nine groups to study some of the lesser known metals: columbium, molybdenum, zirconium, lithium, beryllium, tantalum, tungsten, thorium, and uranium. Object: to develop specifications for these metals, where needed. Specifications for molybdenum, zirconium, and beryllium have been drafted for study.

The committee issued a specification for titanium and titanium alloy bars and billets (B 348). Also in the titanium field the committee has formally requested the Joint AWS-ASTM Committee on Filler Metals to develop a specification for titanium welding rods and electrodes. The committee sponsored a three-session symposium on newer metals at the Pacific Area Meeting in San Francisco in October.

● METALLOGRAPHY (E-4)

On recommendation of the committee, the Society will issue transparencies of the grain size standards appearing in the methods for grain sizes of metals (E 112). These will be made generally available for use by industry. New grain sizes were added to Plate III of Methods E 112 covering 0.200, 0.150, 0.020, and 0.005-mm diameters of twinned grains using a contrast etch.

An extensive program was begun to determine present-day requirements concerning inclusions and their evaluation. It is evident that the several branches of metallurgical interests are concerned with different kinds, amounts, and distributions of inclusions as a function of the production process, material, or product.

The subcommittee on electron microstructure is currently concerned with reactions in the high-temperature superstrength alloys and in the studies of these and other materials by transmission methods on specially prepared thin foils. Techniques for foil thinning will be investigated.

● NONDESTRUCTIVE TESTING (E-7)

A most important document on radiographic testing—a method for controlling quality (E 142)—was published last year. Requirements expressed in this method are intended to control the reliability or quality of radiographic images and are not intended for controlling the acceptability or quality of materials or products.

With the help of several committees of the Aerospace Industries Assn., the committee has prepared an album of reference radiographs for aluminum and magnesium castings. These radiographs are reproduced directly by radiographic rather than by photographic means.

A very extensive program is in progress to develop reference radiographs for heavy steel castings of 3, 6, and 12-in. sections. This project is supported partly by a grant from the ASTM Administrative Committee on Research, and additional funds have been solicited from industry with the cooperation of the Steel Founders Society.

● EFFECT OF TEMPERATURE ON PROPERTIES OF METALS (JOINT WITH ASME)

Procedures for conducting tension tests (E 151) and creep tests (E 150) of

metallic materials at elevated temperatures under conditions of rapid heating and rapid strain rates have been published. These methods, long needed in the aircraft industry, are intended to provide some basis of standardization for certification, capability, and acceptance testing of metallic materials for airframes and missiles.

The committee has under way two research projects aimed at finding answers to some of the tubing problems in power plants. One investigation is probing the causes of cracking in weld-affected zones of austenitic steam lines in power plants. Several developments to date have reduced the frequency of cracking, but still needed is basic knowledge about the causes.

A second project in this field is an investigation of the excessive creep and premature failures being experienced with certain stainless steel superheater tubes. In less than a year of research a temporary solution has been instituted by the adoption of new provisions in certain ASTM specifications and in the code stresses of the ASME Boiler and Pressure Vessel Committee. This study is continuing in order to establish the basic relationship of composition and metal structure of austenitic steels to service performance under creep conditions.

Last year, the committee inaugurated a fund drive to raise $150,000 to support research projects for the next several years. After six months of intensive effort, almost this full amount has been subscribed.

With publication of the Report on the Properties of Cast Iron at Elevated Temperatures, *STP 248*, a 5-yr research project sponsored by the committee was brought to a close.

Construction Materials

• CEMENT (C-1)

Evaluation of a number of additives used as grinding aids in cement manufacture has led to the development of a specification for nonharmful additions to cement. The availability of this specification to the industry will greatly simplify the responsibility of the committee and relieve it of the need for careful review of each product. This specification will be similar in nature to the present specification for air-entraining additions for use in the manufacture of air-entraining portland cement (C 226).

Significant changes were made in the widely used specifications for portland cement (C 150 and C 175). They involve deletion of requirements for tricalcium silicate for certain types and, for others, addition of requirements for heat of hydration.

• CHEMICALLY RESISTANT MORTARS (C-3)

The most significant property of mortars, but the most difficult to standardize a test method upon, is chemical resistance. Method C 267, standard since 1954 for testing hydraulic cement mortars, has now been broadened to cover also the resin, silicate, and sulfur types. The test method makes use of weight change of specimens and appearance of both specimens and test solutions as guides for selection of mortars for particular applications. Compressive strength is also an important criterion in the analysis.

• CLAY PIPE (C-4)

Clay liner plates are being widely used to provide resistance in pipe to corrosion or erosion due to acid, alkali, scouring waste water, and other liquids. A specification was developed during 1959 to cover this type of product. Extra-strength perforated clay pipe requirements have been prepared for inclusion in the present specification for standard strength perforated clay pipe (C 211) or for separate publication.

• LIME (C-7)

The need for specifications for limestone for use in the various chemical and process industries was given special attention during 1959. It was concluded that in view of the diversity of requirements for lime in such industries as agriculture, steel, and glass, a universal specification is not considered feasible now. This field will be watched, however, by a permanent subcommittee.

The use of pozzolans with lime was actively studied by means of round-robin test programs.

• CONCRETE AND CONCRETE AGGREGATES (C-9)

The growing use of epoxy resins in concrete construction has led to the study of this group of materials and the possible need for standards.

Performance requirements for concrete used for nuclear radiation shielding are now definitely under consideration by a newly formed working subcommittee, which expects to develop standards.

Testing techniques for vibrated concrete have been found to be a necessary area of development. A test program has been under way to evaluate a proposed procedure for vibration of concrete testing cylinders.

The evaluation of lightweight concrete, with a view to the development of standards, has been undertaken in conjunction with the work on lightweight aggregates.

The effectiveness of mineral admixtures in preventing excessive expansion of concrete due to the alkali-aggregate reaction can be determined by a new method of test (C 441) developed and accepted during 1959.

• MASONRY MORTAR (C-12)

Work was completed in 1959 on a procedure for quantitative evaluation of efflorescence. This procedure was published in the ASTM BULLETIN, January, 1959. The influence of sand gradation on the properties of masonry mortar was an important study under way during the year.

• CONCRETE PIPE (C-13)

The requirements for joints for circular concrete sewer and culvert pipe, using flexible, watertight, rubber-type gaskets, are now covered in a new specification (C 443) accepted in 1959.

The first specification to cover perforated concrete pipe was completed and accepted by the Society. This specification (C 444) is intended to be used for underdrainage.

• MANUFACTURED MASONRY UNITS (C-15)

A completely new revision of the specification for clay drain tile (C 4), originally published in 1914, was completed and accepted by the Society in 1959. This marks the final separation of requirements for clay and concrete drain tile, the latter now being covered by specification C 412.

Marked progress was made during the year in the exploratory work leading to the development of standards for evaluating the effectiveness of water-retardant materials. The use of a weathering index in establishing the effect of weathering on brick has provided significant data for use with the specifications on brick.

• THERMAL INSULATING MATERIALS (C-16)

The trend of activity turned toward emphasis on the development of specifications for thermal insulation required in home construction, rather than industrial uses.

The committee is considering a new philosophy of writing specifications based on performance rather than on materials composition, which has been the practice to date. This would result in specifications for certain classes of use, irrespective of composition of the material.

Foamed-in-place thermal insulating materials is one of the newer types of material to which attention was given during the year.

Review of the ASTM Year—1959

• ACOUSTICAL MATERIALS (C-20)

Fire resistance of acoustical tile received much attention during 1959. The committee sponsored one of the first known research programs to evaluate the reproducibility of test results of the "tunnel type" test apparatus (E 84) among several installations. The results of this program have been turned over to Committee E-5 on Methods of Fire Tests for further correlation.

An active industry group has been evaluating the many types of mechanical suspension systems for acoustical tile ceilings, with the objective of developing test procedures that will help establish standards in this important field.

• JOINT SEALANTS (C-24)

The sealing of joints in many types of construction, from aircraft to highways, and particularly in buildings, has led to a diversity of caulking compounds and sealants. Too much diversity creates confusion, and the need for standards is evident. So in 1959, the Society established the new Committee C-24 on Joint Sealants to develop standards for these materials. The committee has organized working subcommittees covering nomenclature, bulk compounds, and preformed shapes.

• ROAD AND PAVING MATERIALS (D-4)

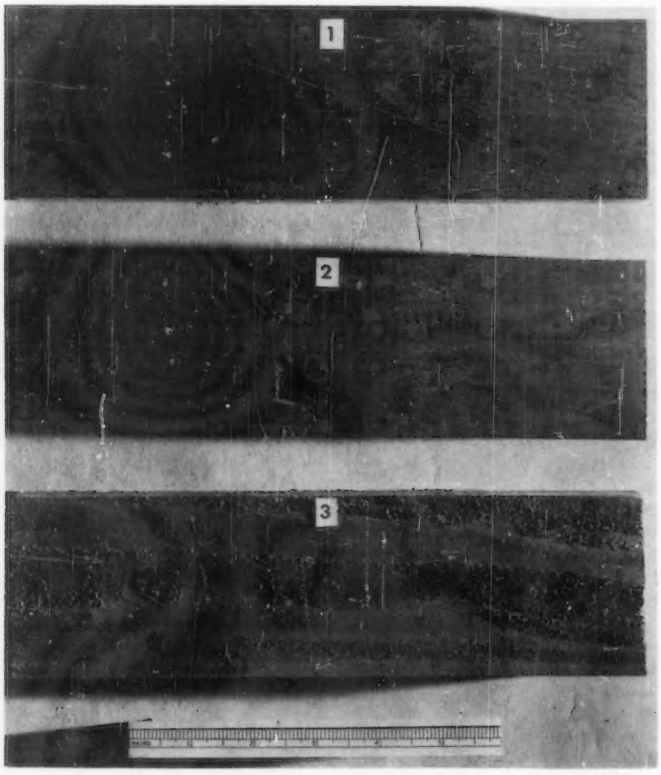
Committee D-4 will prepare a manual of recommended practices for the design of bituminous paving mixtures. It will include methods of testing bituminous mixtures and information on the preparation of aggregates.

Coating and demulsibility tests for bituminous emulsions are being worked on with new intensity as the technology in this field advances.

• WOOD (D-7)

Problems relating to the sawing and machining of wood are of international interest and importance. The development and acceptance in 1959 of a method of conducting machining tests of wood and wood-base materials (D 1666) was one of the major contributions of the committee toward solution of these problems. The method can be used to determine the working qualities and characteristics of different species of wood and of different wood and wood-base materials under a variety of machine operations.

A proposed standard for the pressure treatment of timber products was developed and is being correlated with the American Wood Preservers Assn. This will cover various species and types of material and is applicable to each of the treating processes.



RESULTS OF PLANING TESTS ON WOOD

(1) and (2) black walnut; (3) mahogany.

• BITUMINOUS ROOFING AND WATERPROOFING (D-8)

Woven glass cloth treated with either asphalt or coal-tar pitch provides a very satisfactory membrane system for waterproofing. This material is now covered by a specification (D 1668) developed by Committee D-8 and accepted by the Society in 1959.

An expansion of activity during the year was the organization of a subcommittee on industrial pitches.

• SOILS (D-18)

Collaboration with other technical and engineering societies was very much in evidence during 1959. The comprehensive list of definitions and symbols relating to soil mechanics (D 653) is the result of joint activity of subcommittees in ASCE and Committee D-18. It is now agreed to form a permanent joint subcommittee to continue this activity. Further emphasis on definitions was evident in the acceptance of a list of terms relating to soil dynamics.

Members of the committee will assist in the preparation of a book to be titled "Methods of Soil Analysis" sponsored by the American Society of Agronomy.

Projects are in progress to develop methods covering permeability of granular soils, bearing rates of soils (California Bearing Ratio), density of soil-in-place by the rubber balloon method, and four methods pertaining to cement for stabilization of soils.

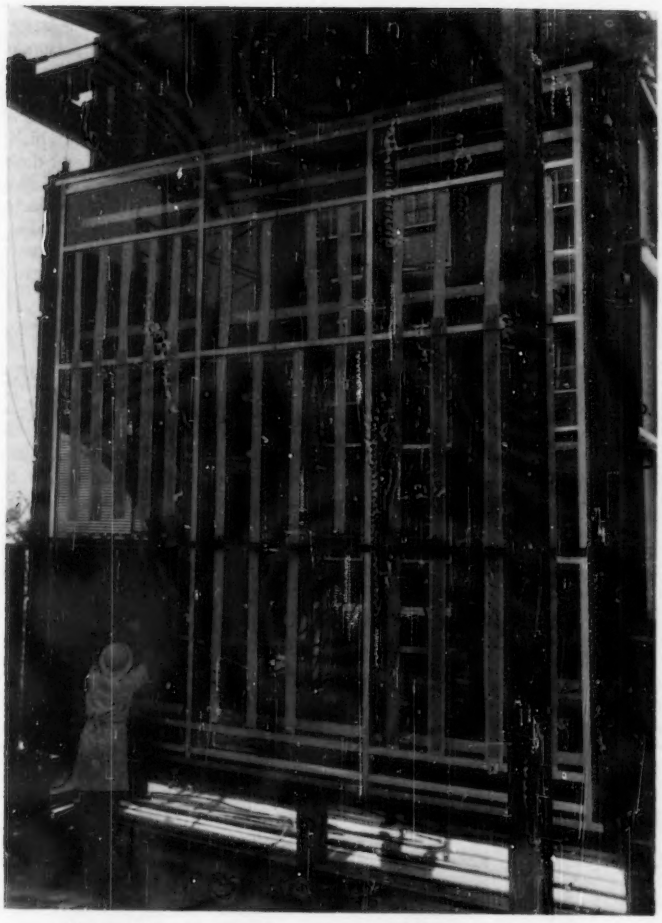
• FIRE TESTS (E-5)

The "tunnel test" method (E 84) was substantially revised in 1959 to conform to present practice. Suspended ceilings, not an integral part of a floor construction, were recognized and included in the standard methods of fire tests (E 119).

Intensive study has been underway in the consideration of so-called "small-scale" test procedures for determining flame spread of acoustical and other interior finishes. This includes the radiant panel and the small-scale tunnel test. Both evaluation and code approval are involved; one objective: to reduce testing cost and time by use of small-scale tests.

• BUILDING CONSTRUCTIONS (E-6)

Test methods for unit masonry assemblies and for vapor barriers for concrete ground slabs and crawl spaces represent two major accomplishments during the year. The latter method fulfills a long-



STATIC TEST CHAMBER FOR GLASS CURTAIN WALL PANELS

By partial evacuation of test chamber, wind loads of velocities up to 110 mph can be simulated.

standing need expressed by the Federal Housing Administration.

The sponsorship of a symposium on testing window assemblies during the 1959 Committee Week inaugurated a new project in developing standards for the evaluation of this important item in building construction.

These two projects are an indication of the great potential that this committee has to be of service to the building industry and building code authorities.

● REFRACTORIES (C-8)

A new classification for chrome-magnesite brick, magnesite-chrome brick, and magnesite brick has been proposed. This classification will be based on the obvious differences in magnesium hydroxide content of commercially produced brick.

An interlaboratory study of the method for permeability of carbon refractories has been completed. A new method of determining the thermal conductivity of ordinary refractories has been initiated. Work on a specification for pouring pit refractories is nearing completion.

A method of test for hydration resistance of basic brick has been submitted to the committee for review.

● CERAMIC WHITEWARES (C-21)

The development of further methods to characterize clays involves determining the range of particle sizes by the hydrometer and centrifuge methods, determining the organic content, and detecting the presence of soluble sulfates. Methods of testing the overglaze of ceramic ware include craze testing by thermal shock, lead solubility, alkali attack of overglaze decoration, and water absorptiveness. Development of a test for translucency of ceramic whitewares has reached the interlaboratory testing stage.

● PORCELAIN ENAMEL (C-22)

The evaluation of porcelain enamels is being enlarged to include tests for bubbles or voids in enameling, and surface defects such as ripples and crazing. Tests being completed cover acid resistance of porcelain enamel, refractivity and coefficient of scatter, a torsion test and spall resistance of aluminum alloys

● SORPTIVE MINERAL MATERIALS (C-23)

Bulk and tamped density of sorptive mineral materials are being submitted for an interlaboratory cooperative test program. Other methods being studied include solubility in water, absorbency, and water breakdown.

Electrical and Electronic Materials

The wide diversity of materials having magnetic and electrical properties of interest to the electrical and electronic industries is illustated by the fact that they appear in the ASTM organization in the "A" group (ferrous metals), the "B" group (non-ferrous metals), the "C" group (cement and ceramics materials), the "D" group (miscellaneous materials) and in the "F" group (materials for specific applications). They include Committees A-6 on Magnetic Properties, largely concerned with the properties of core materials for transformers, motors, and the like at low and power frequencies; B-1 on Electrical Conductors; B-4 on Resistance, Heating, and Thermostat Materials; D-9 on Electrical Insulating Materials; D-11 on Rubber, including subgroups on wire and cable and electrical protective equipment; D-27 on Electrical Insulating Liquids and Gases; and F-1 on Materials for Electron Tubes and Semiconductor Devices. Also included are certain subgroups of Committee C-21 on Ceramic Whitewares covering high dielectric-constant materials such as the titanites and zirconates and the ferrites used as high-frequency magnetic core materials and for computer applications.

● MAGNETIC PROPERTIES (A-6)

For some ten years the AIEE magnetics committee has been concerned with problems of magnetic amplifiers and in particular nonlinear magnetics. In 1958 the AIEE published two proposed standards relating to these materials, one for presenting data on magnetic amplifier core materials and the other a recommended practice for toroidal magnetic-tape-wound cores. Based on these two documents and other work of the AIEE magnetic amplifier committee, Committee A-6 has been developing methods of test for tape-wound cores. The committee is also developing methods for evaluating the magnetic shielding characteristics of

various materials. Test methods are already available for making measurements of the intrinsic properties of magnetic materials, but there are no standardized test methods for measuring properties of fabricated parts.

The committee is also revising its extensive definitions for magnetic terms (A 340). Also under active revision are methods for permeability of feebly magnetic materials (A 342), methods for a-c magnetic properties of Epstein specimens (A 343), and methods for electrical and mechanical properties of magnetic materials (A 344).

● ELECTRIC CONDUCTORS (B-1)

During the past few years there has been a growing commercial interest in aluminized steel-core wire for steel-reinforced aluminum conductors. Taking note of this trend the committee has developed a new specification for aluminum-coated (aluminized) steel core wire for aluminum conductors, steel reinforced (ACSR) (B 341).

In answer to a specific request, the committee issued a method of test for electrical conductivity by use of eddy currents (B 342). It was felt that since this method was being used commercially on certain conducting materials such as bus bars, a formal procedure was needed.

● RESISTANCE, HEATING, AND THERMOSTAT MATERIALS (B-4)

Research aspects of electrical contacts occupy a great deal of the committee's attention. It is a usual custom at meetings to invite some researcher not associated with the committee to present the results of his work. The committee also keeps up to date with annual supplements to its long-standing bibliography and abstracts on electrical contacts (*STP 56*).

The committee has been studying various methods for accelerating contact deterioration so as to assess the quality of contacts under various environmental conditions. To supplement this work and to develop some correlation with exposure under natural conditions, the committee last year inaugurated a program to expose contacts at various ASTM exposure sites. The corrosive effects of these natural and industrial environments will be evaluated by a periodic inspection and testing of the contact assemblies at the test sites.

In the area of standardization, the committee has established a new specification covering drawn or rolled nickel-chromium and nickel-chromium-iron alloys for electrical heating (B 344) to replace the former specifications B 82 and B 83. The committee also established a new tentative method of accelerated life test of heating alloys (B 343).

● ELECTRICAL INSULATION (D-9)

Test methods relating to thermal stability of electrical insulation have occupied much of the attention of the committee in recent years. The activities are coordinated with those of other organizations in the electrical field, particularly AIEE and NEMA, with the general objective of establishing thermal classification based on performance rather than composition. An important contribution of the committee toward adequate classifications was the publication, as information, of a method for thermal stability of coated sleeving using dielectric breakdown as a criterion. This was published both in the committee's Annual Report and in the recently published compilation of ASTM Standards on Electrical Insulating Materials. This method supplements two earlier methods for evaluating thermal stability of coated fabrics using curved electrodes, one by dielectric proof tests and the other by dielectric breakdown. After a suitable trial period, it is expected that all of these methods will be established as tentative, possibly in some modified form.

A number of new tentatives were established, including a new method for evaluating dielectric properties of expanded cellular plastics, methods for testing mica paper, and methods for testing frictional characteristics of magnet wire.

● INSULATING LIQUIDS AND GASES (D-27)

Early in 1959, the Society's activity in standardizing insulating liquids and gases was established as a new committee, previously a subcommittee of Committee D-9. A history of the activities of the group, going back as far as 1916, appeared in the May 1959 ASTM Bulletin.

Much of the committee's work has been of special interest to the electrical utilities, since it has dealt with the problems of liquid insulation in power transformers and in power cables including the problems of deterioration and rejuvenation of these materials. Adding to the number of standards in this field last year, the Society published a new tentative method for sediment and soluble sludge in service-aged insulating oils (D 1698).

New work on gases: In organizing as a separate committee, the scope was broadened to cover gaseous insulation While gases under pressure have long been used for cable insulation, there have apparently been no special problems of standardization until recently. Several chemical compounds have become available commercially which have outstanding properties as dielectric materials. Because of this industrial interest and the variety of products that seem likely to become available, the committee has established a subcommittee on gases. Efforts to date have been mostly organizational.

● ELECTRON TUBE AND SEMICONDUCTOR MATERIALS (F-1)

The committee continues its long-standing important work on the development of standards for electron-tube cathodes. Recent findings reported at the committee's 1959 fall meeting by Bell Telephone Laboratory researchers indicate that considerable improvements can be made in emission properties and freedom from interface impedance by closer control of composition of cathode nickel.

The committee established a new activity toward the development of standards for control of contaminants in electron-tube and semiconductor manufacture. The new group will establish standards for purity of cleaning materials as well as the cleanliness of the atmosphere in areas where parts are assembled. This activity received its impetus from the Symposium on Cleaning Electronic Devices and Materials (*STP 246*) held in late 1958 and published by the Society.

Another new activity of the semiconductor group is in the establishment of standards relating to thermoelectric materials. In many ways these materials have properties in common with other types of semiconductors used for such solid state devices as transistors and diodes.

● CERAMICS FOR ELECTRONICS (C-21)

Several subgroups of the ceramic whitewares committee are concerned particularly with ceramics having special properties of interest for use in electronic components. A subcommittee on nonmetallic magnetic materials is concerned with microwave ferrite applications and has about completed development of two methods covering ferrimagnetic resonance linewidth and gyromagnetic ratio, and complex dielectric constant of nonmetallic magnetic materials.

Another task group is concerned with computer applications and has about completed work on a method of testing nonmetallic magnetic cores to be used in a coincident current memory with a 2:1 selection ratio.

Organic and Polymeric Materials

● PAPER (D-6)

Committee D-6 is working closely with TAPPI in the development of the Elmendorf test of cylinder boards and revisions of the methods for basis weight of paper and paper products (D 646), flammability of treated paper and paperboard (D 777), and the tensile breaking strength of paper (D 828). New modifications in the diaphragm for bursting strength of paper (D 774) have necessitated new interlaboratory work on this test.

● RUBBER (D-11)

The abrasion resistance of rubber soles and heels can now be tested by an ASTM method (D 1630) recently developed by Committee D-11 on Rubber. New fields of application are opening up for the great variety of products based on expanded cellular rubber, plastics, and elastomers. To bring order to this fast growing field, new specifications and tests were established covering cellular materials of poly(vinyl chloride) or copolymers (D 1667). Previously established were specifications and tests covering urethane foams, as well as the longstanding specifications and tests for latex and sponge rubbers.

With the increase in automotive air conditioning, it is worth noting that the Society has developed, jointly with the SAE, methods of testing automotive air-conditioning hose (D 1680).

● TEXTILES (D-13)

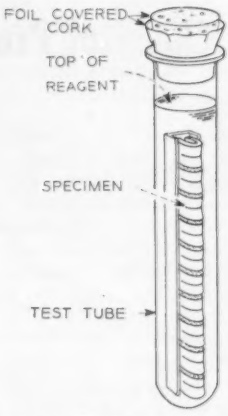
A very large market for textile materials is in reinforcing cords for tires. Committee D-13 has revised the methods of testing and tolerances for tire cords from man-made fibers (D 885) and has included an appendix describing in-rubber fatigue methods for textile tire cords.

Grading cotton for color difference requires very careful control of lighting in the grading area, and to remove this factor as a variable in color grading of cotton, Committee D-13 developed a new recommended practice for lighting such rooms (D 1684).

The general methods of testing woven fabrics (D 39) are being extensively revised. The first part of the revision has been issued in the form of two new tentatives, one under the old designation (D 39) covering construction characteristics of woven fabrics, and the other under a new designation (D 1682) covering breaking load and elongation testing of textile fabrics.

● PLASTICS (D-20)

Polyethylene—known to the layman in the form of large plastic containers, refrigerator ware, and unbreakable toys—is also widely used in industry for electrical insulation and protective sheaths for cables. It is in this latter application that the tendency of the material to crack under stress in certain environments was first observed. To aid in its selection of materials that would be resistant to environmental stress cracking, the Bell Telephone Laboratories developed the well-known bent strip test for evaluating stress cracking. This test has now been established as an ASTM method (D 1693).



APPARATUS FOR ENVIRONMENTAL STRESS CRACKING TESTS OF BENT PLASTIC STRIPS

A significant first: A new test for flammability of plastic foams and sheeting (D 1692) provides for the first time a method for evaluating flammability characteristics of cellular plastics. The method is also applicable to flexible sheet materials. General applicability of the method to all types of cellular materials has not been established but is currently under study.

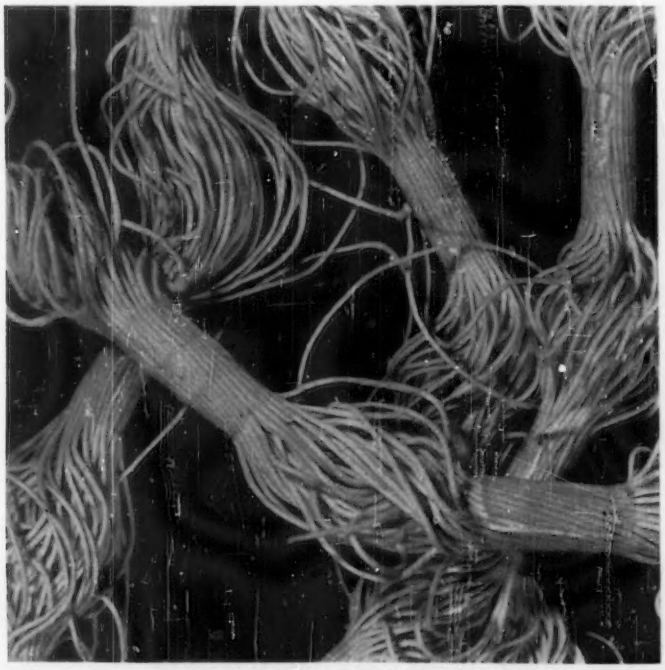
Several new methods and specifications relating to plastic pipe were developed and approved during the year and a new subcommittee on plastics tooling has been organized.

The committee provided USA participation in the work of ISO Plastics Committee which met in Munich, Germany, in October. ASTM standards on plastics are the basis for many of the internationally recommended test methods for plastics.

● CELLULOSE (D-23)

Test methods for cellulose are being standardized world-wide through the testing of standard samples distributed by the International Committee on Cellulose Analysis. Committee D-23, which is carrying out the tests in the USA, is preparing methods that will be recommended to the Society as tentative.

The committee is investigating methods for molecular weight of cellulose



MODEL OF POLYMER MOLECULES IN A CRYSTALLINE PLASTIC
Each string represents a molecule; the bundles represent elementary fibrils.

based upon measurement of disperse viscosity and is preparing additional procedures and methods of testing cellulose acetate (D 871) and cellulose acetate butyrate (D 817).

• CASEIN (D-25)

Methods to determine ash, fixed ash, free acidity, alkali requirement, and oil content are being submitted for final action.

Interlaboratory tests have been conducted on sieve analysis of casein and soy protein, dirt content, foaming, insolubles, minimum alkali requirement, viscosity of solution, and odor. The data from these tests are being used as a basis for further refinements prior to the next interlaboratory study.

Chemical Products and Petroleum

• PAINT (D-1)

Since 1923, methods of testing varnishes (D 154) have appeared in the ASTM Book of Standards. The methods were revised many times during the past 36 years. In 1959, designation D 154 was revised, and individual methods for testing varnishes were recommended and approved as separate standard methods. The new standard tests for varnishes cover: Nonvolatile Content (D 1644), Elasticity or Toughness (D 1642), Acid Value (D 1639), Reactivity of Paint Liquids (D 479), Resistance to Water and Alkali of Dried Film (D 1647), Drying Times (D 1640), and Exterior Durability (D 1641).

The committee also recommended and the Society approved nine new tentative specifications and methods, including two new specifications for pigments: for strontium chromate (D 1649), and for basic lead silico-chromate (D 1648). Also included was a test for epoxy content of epoxy resins (D 1652).

In cooperation with ISO 35 on Raw Materials for Paint, Varnish, and Similar Products, a new tentative method was established covering sampling and testing shellac varnish (D 1650), and revisions were made in methods for sampling and testing lacquer resins (D 29).

• PETROLEUM (D-2)

Committee D-2 on Petroleum had the distinction of turning out the second largest Annual Report—105 pages—reflecting the very high rate of activity in standards for petroleum products and lubricants as well as for hydraulic fluids. Some statistics on the report: accepted for publication as information only, 10 items; accepted as tentative, 8 items; revised, 27 items.

The ASTM Manual for Rating Motor Fuels by Motor and Research Methods, currently under revision, is expected to be completed early this year. The committee completed in 1959 the revised Manual for Rating Diesel Fuel by the

ELECTRON MICROGRAPH OF SOAP FIBERS

Cetane Method. This widely used method permits the determination of ignition quality by comparing performance of the test fuel with blends of reference fuels of known cetane number under standard operating conditions in a test engine. When fuel is injected into the combustion chamber of a diesel engine, ignition does not occur immediately. The interval between the beginning of fuel injection and its auto- or self-ignition is known as the ignition delay period. The shortest delay period corresponds to a cetane number of 100. If the delay is too long, the engine may be hard to start and will run roughly. If the delay is short the engine runs smoothly.

The committee has extended the research method for evaluating gasolines over 100 octane number (D 1656) and has published as information a method for octane numbers above 100 by the motor method.

Signaling the arrival of the jet age are several methods pertaining to jet and turbine fuels—tests for thermal stability (D 1660) and proposed tests for luminometer numbers and for filterability.

• COAL AND COKE (D-5)

Intensive interlaboratory work is continuing on the development of methods for the mechanical sampling of coal. New work has been initiated on standardizing the Giesler plasticity test and Bethlehem oven test for change in volume, and the Russell oven test for change in pressure of coking coals. Additional methods of analysis of coal include determination of sulfur in coal ash, mineral carbonates in coal, and a revision of the fusibility of coal ash.

• SOAPS AND OTHER DETERGENTS (D-12)

A significant first: a new method using the combined techniques of ion exchange and chromatography, a revision of the analytical methods for sodium triphosphate (D 501). This development of Committee D-12 was reported at the 1959 Annual Meeting.

• ENGINE ANTIFREEZES (D-15)

Data from the first interlaboratory test of the new bench-type apparatus for testing the corrosion and foaming properties of engine antifreezes under simulated service conditions have been obtained. Further study of the variables is under way in the committee.

Work is continuing on a foaming test of antifreezes and analysis of glycols in antifreezes.

The committee revised its method for the determination of water in antifreezes using the iodine reagent (Karl Fischer) method. The determination uses a modified Fischer reagent to minimize undesirable and interfering reactions which cause high results due to presence of carbonyl compounds.

• AROMATIC HYDROCARBONS (D-16)

Work is under way on methods for tar acids, phenol assay, and the water solubility of refined phenol. Collaborative work is continuing on methods for refined pyridine and quinoline.

Methods are being developed for pythalic anhydride to include: heat color, color of melt, and solidification point.

The committee completed development of a test for color of solid aromatic hydrocarbons in the molten state (D 1686) and a test for traces of thiophene in benzene (D 1685).

• NAVAL STORES (D-17)

Interlaboratory work on rosin is continuing on a study of methods to determine the softening point, to measure the crystallization tendencies, and to determine the acid number and saponification number. The objective is to improve present methods or to replace them with improved new methods.

Work is continuing on three methods for the determination of fatty acids in tall oil rosin.

● WAX POLISHES (D-21)

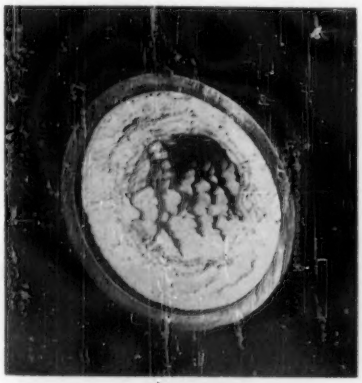
New methods being submitted to ballot are for the determination of water and abrasives in automobile polish. Methods to evaluate water spotting, stability of packaged adhesives, and removability of applied wax polish are being developed. Work has been initiated on analysis of polymers in emulsion wax polishes.

● INDUSTRIAL WATER (D-19)

Three new tests of special interest in the use of water in nuclear reactor power plants have been published: tests for copper and silica in high-purity water (D 1688 and D 1689) and method for measurement of gamma radioactivity of industrial water and waste water (D 1690). The committee also established methods for chromium (D 1687) and for zinc (D 1691) in industrial water.

The second edition of the manual on industrial water and industrial waste water has been completed and will be available soon.

Water for electronic cleaning has occupied the attention of Committee F-1 on Materials for Electron Tubes and Semiconductor Devices. For this use, water having extremely low conductivity derived solely from ionization of the water molecule is used, and tests for measuring the degree of purity are being developed in cooperation with Committee D-19.



PIPE PLUGGED BY WATER-FORMED DEPOSITS

Coordination, Analysis, and Testing

The "E" committees of the Society, numbering 1 through 16, cover subjects not generally limited to particular materials or classes of materials and therefore have a dual function in the Society: (1) to cover general fields of testing and to serve as a forum for those interested in establishing general methods in the field, and (2) to coordinate activities in those areas where more than one committee is working on a similar project. The coordination function of the "E" committees is an important one. It helps to reduce duplication in the Book of Standards, but even more important, it reduces duplication of effort within the various committees interested in the same subject.

● METHODS OF TESTING (E-1)

Committee E-1 last year established three new tentatives covering specifications for laboratory ovens (E 145), method for shear modulus (E 143), and recommended practice for safe use of oxygen combustion bombs (E 144). The committee also published with its annual report important revisions in the specifications for ASTM thermometers (E 1), involving a new method of dimensioning which significantly improved the quality of the thermometers and simplified manufacturing problems. Three new thermometer specifications were added covering weathering test thermometers (No. 99F) and two solidification point thermometers (Nos. 100C and 101C). The committee also established new specifications for microchemical apparatus for determination of nitrogen by the Dumas and Kjeldahl methods (E 148 and E 147).

● EMISSION AND ABSORPTION SPECTROSCOPY (E-2 and E-13)

All current techniques in emission and absorption spectroscopy, including the newer magnetic resonance techniques, X-ray emission spectroscopy, and flame photometry, were discussed at a symposium in October sponsored jointly by Committees E-2 and E-13. NMR and EPR spectroscopy were covered in four papers and are of sufficient interest in Committee E-13 that a new subcommittee on nuclear magnetic resonance and related techniques has been established to prepare standards in this field. The committee has also established a group on X-ray fluorescence spectroscopy.

Emission. Definitions relating to emission spectroscopy have been expanded by the addition of 42 new terms. Standard definitions such as these help greatly to improve communications in specialized fields which tend to become more complicated as they become more specialized. Such definitions not only improve communications within the field but also with other related specialties which may have somewhat different jargons.

Continuing its long-standing program of indexing the literature on spectrochemical analysis, the Society has published Part IV of the Index (*STP 41D*); Part III of the Index covers the period 1946 to 1950. Part IV covers the period 1951 to 1955.

Absorption. Recommended practices covering general technology for infrared and ultraviolet quantitative analyses have been published as special pamphlets. These recommended practices should be helpful not only to other ASTM committees concerned with this problem but also to industrial laboratories generally using these techniques. The definitions relating to absorption spectroscopy have been broadened with the addition of 18 new terms. Here again, nomenclature in a specialized field is being standardized to improve communications.

A significant first: The first portion of the Empirical Formula-Name Punched Card Index to Ultraviolet Spectra was issued in 1959.

● MASS SPECTROMETRY (E-14)

The impact of electrons upon simple molecules, thermal degration of polymers, precise measurement of radioactive masses, and the role of mass spectrometry in space research, were subjects of four of the 81 papers presented at the week-long meeting in May, 1959 of Committee E-14 on Mass Spectrometry. This extensive program of papers covering a very large area of technology where mass spectrometry is finding application provides a national forum for papers on this subject and for exchange of information.

● FATIGUE (E-9)

A matter of great interest and some urgency to the airframe industry—fatigue of aircraft structures—was the subject of a 3-session symposium at the Pacific Area Meeting in San Francisco. In the eleven papers presented many new investigations were reported, particularly in the areas of sonic and low-cycle fatigue.

The fatigue committee completed the first step in a long-range program to revise the "Manual on Fatigue Testing," *STP 91* (1949). Revised definitions and symbols relating to fatigue testing and to the statistical analysis of fatigue data were developed. These revisions will replace the definitions now published in the manual and in its supplement, *STP 91-A*.

The annual list of "References on Fatigue" abstracting articles published in 1958 dealing with fatigue of structures and materials was issued during the year.

Review of the ASTM Year—1959

• RADIOISOTOPES AND RADIATION EFFECTS (E-10)

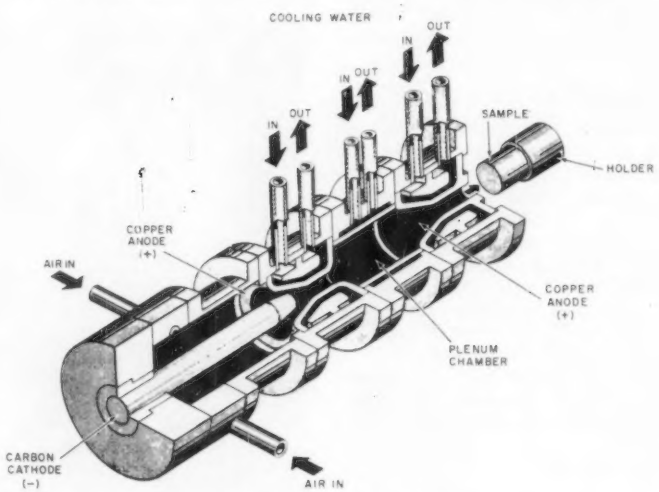
Committee E-10 sponsored two symposia at the Pacific Area Meeting in October. Papers in the two-session Symposium on Application of Radioisotopes in the Testing of Materials are the basis for drafts of several test methods which will be submitted to the Society for approval soon.

The second symposium comprised three sessions on radiation effects and dosimetry. Most of these papers will be published by the Society in a volume on radiation effects on materials for nuclear reactors.

A task group is canvassing technologists in the nuclear reactor field in an attempt to pinpoint the problems involved in the procurement of suitable materials. It is intended that such information will be transmitted to the appropriate ASTM committee for possible development of specifications and test methods in this problem area.

• INDUSTRIAL CHEMICALS (E-15)

About 60 companies were represented by the 100 members of Committee E-15 who attended the first full-scale meeting of the committee at the 1959 Annual Meeting of the Society. Subjects of active projects include statistics and sampling; development of methods for chlorine, sulfur, hydroxyl groups, and unsaturation in organic compounds; development of uniform temperature-density tables for industrial organic liquid chemicals; development of a standard method for determination of water in chemicals; and development of test methods for such products as sulfuric acid, sodium hydroxide, and alcohols. Members and officers of the committee are enthusiastic about the possibilities of making significant contributions resulting in savings to the chemical industry.



PLASMA JET APPARATUS

This apparatus produces a subsonic jet of arc-heated air for laboratory simulation of reentry conditions in thermal ablation tests.

This is one of a series of photographs from a collection compiled by Prof. Jasper O. Draffin and displayed in the Arthur N. Talbot Laboratory, University of Illinois.

RENÉ DESCARTES (1596–1650). The greatest of French philosophers. Probably best known for his invention of analytical geometry. Devoted much of his energy to the study of metaphysics. In his attempt to geometrize all of nature, he made outstanding contributions both to the field of mathematics and to that of theoretical physics.

"Good sense is, of all things among men, the most equally distributed; for every one thinks himself so abundantly provided with it, that those even who are the most difficult to satisfy in everything else, do not usually desire a larger measure of this quality than they already possess."

. . . Discourse on Method

Old Wine in New Bottles

A New Look at the Substance, Water[1,2]

By FRANK E. CLARKE,[3]

It is safe to say that everyone considers water a genuine necessity. On the other hand, few on first thought would consider it a competitor, in novelty and glamour, to space-age wonders like nuclear power plants, earth satellites, and moon rockets. Perhaps we are so close to this commonplace substance that our picture of it is not clearly focused. It is time we took a new and better look, for water undoubtedly is destined eventually to become the most important of our natural resources.

The Inside Dope

Our new look should start inside the water molecule, where modern concepts of structure reveal features that make for interesting potentialities.

Concepts of the water molecule have matured with the orderly transition from classical through atomic to nuclear physics. No longer is the hydrogen atom pictured according to the basic Bohr concept of a satellite electron orbiting about a simple proton nucleus in a series of roughly circular concentric paths representing as many energy levels. Instead, it is represented as a relatively complex nucleus surrounded by a variety of somewhat abstract electron clouds (Fig. 1), each representing a possible standing wave pattern, the product of a particular mass-energy relationship of the electron. These clouds are graphic representations of Heisenberg's famous uncertainty principle that says, in effect, it is certain only that the electron is somewhere in one of these clouds. The more certain its location, the less certain its movement, for the means of measuring one property hinders measurement of the other.

The nucleus within these standing wave patterns of electrostatic influence may be the basic proton variety some of us studied in high school or the heavy or extra-heavy nuclei of deuterium (one neutron plus one proton) or tritium (two neutrons plus one proton). In any case, there will be an energy-level pattern for the nuclear particle or particles rivaling that of the satellite electron and too complicated for proper discussion here.

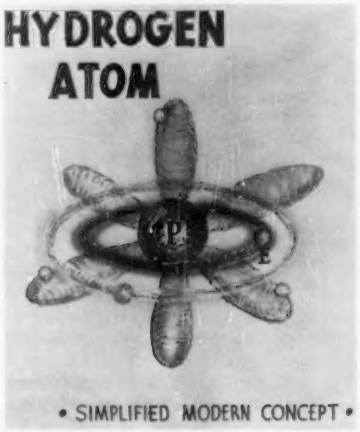


Fig. 1.

The oxygen atom is built on the same pattern as that of hydrogen, but it is far more complicated because of its greater number of electrons and nuclear particles. For example, the eight electrons must jockey for position in the electron clouds according to Pauli's exclusion principle, which permits only two (and these with opposite spins) to occupy a given orbital. The nucleus may have 8, 9, 10, or even 11 neutrons in addition to its complement of protons, yielding atomic weights of 16, 17, 18, or 19.

One would certainly guess that these two components will produce a great variety of molecules (isotopes), and they do. Water, once considered to be H_2O, now comes in at least 18 different varieties of molecular structure, not counting compounds of the short-lived oxygen-19 (less than 1 min half-life). Of these, deuterium oxide (D_2O), representing about 300 parts in every million, is the best known and most widely used special variety (isotope). Tritium compounds are attracting more and more attention.

The macrostructure of water also is complex. For example, there is evidence that each body of water, even the ocean, is a single gigantic molecule, or lattice, which might be written $(H_2O)_n$.

It is paradoxical that the more one learns about the structure of water, the more difficult it becomes to depict it in terms of everyday concepts. Could this be the commonplace substance we have taken for granted?

Interesting New Properties

Locked in the complex atomic and molecular structures of water are the secrets to many unusual properties which continue to appear as explorations in science proceed. Self desalting of sea water, presumably by fractional crystallization and stratification, was reported by the *USS Nautilus* on its historic transit under the polar cap. This process is so effective that a 10- or 12-ft layer of fresh water separates the sea from the ice ceiling in some places. Objects of proper specific gravity will sink through this fresh layer and stop abruptly on the surface of the sea. This is a tantalizing phenomenon to scientists who are attempting to produce the same salt separation by control of crystal growth during freezing.

Equally interesting is the recent evidence that minute nuclei of undissolved solid and gaseous matter cause weak spots in the otherwise strong rope-like structure of water, so that it tears and cavitates, with damaging effects on water-handling equipment. What laymen would buy such a story on first reading? Yet experimenters working on the basis of this theory have reduced cavitation by pressurizing water and the troublesome nuclei to lessen the likelihood of their releasing bubbles and starting tears.

The heavyweight relatives of ordinary water have some peculiar properties too. Deuterium oxide (ordinary heavy water) will not quench thirst, nor will it support plant life. When more is learned about tritium oxide and the other isotopic forms, the list of interesting new properties undoubtedly will expand.

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[1] The opinions in this paper are the author's and do not necessarily represent opinions of the Navy Department or of the Naval Service at large.

[2] Industrial Water Industry Luncheon address, Third Pacific Area National Meeting of ASTM, San Francisco, Calif., Oct. 15, 1959.

[3] U. S. Naval Engineering Experiment Station, Annapolis, Md.

Profitable New Uses

While most of us are seeking new sources of water for the already too numerous uses, others are finding new, interesting uses for the water we already have. Ordinary tap water is being used to indicate radiation intensities by means of the Cerenkov glow, a ghostly bluish-white light it emits when bombarded with charged particles traveling at speeds greater than that of light in water. The high speed is generated by radiation in a vacuum. The wavelength and intensity of the glow indicate the velocity and mass of the impinging particle.

Another somewhat more familiar application based on impinging particles involves the exceptional capacity of deuterium oxide to act as a neutron moderator in fission reactions. In a reactor, the cross-sectional characteristics of the deuterium nucleus are just right for slowing bombarding neutrons, without trapping them, so that they land with a dull thud on the fuel nuclei, with devastating fission effects.

Use of tritium oxide (T_2O) concentration in determining make-up rates in ground waters, particularly captive well waters, is just as interesting. Radioactive T_2O formed by cosmic effects in the atmosphere has a half-life of about 12 years so that its ratio to other water molecules is a real tattletale. Accurate knowledge of water make-up rate is important in seeking dumping grounds for radioactive wastes.

Production of breathing oxygen for the crews of long-submergence submarines by distillation of sea water and electrolysis of the distillate is a less glamorous, but a far more important new use for water. When an electrolyzer of the type shown in Fig. 2 is perfected, man can live under water until he runs out of food or gets homesick.

Traveling a little further into the fantastic, it is conceivable that one might eventually split water into its ions (H^+ and OH^-), as depicted in Fig. 3, and maintain these free radicals immobile with liquid helium refrigeration near absolute zero until their immense recombining energies are reclaimed in rocket engines or other special applications. If you are skeptical of this possibility, better recalibrate your attitude against skepticisms of a decade or two ago.

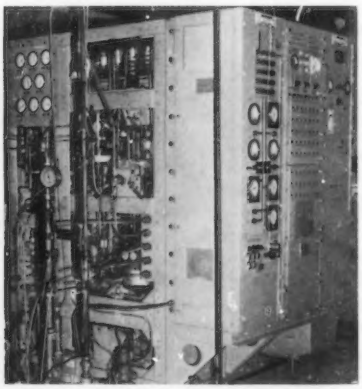

Fig. 2.—Electrolytic Oxygen Generator.

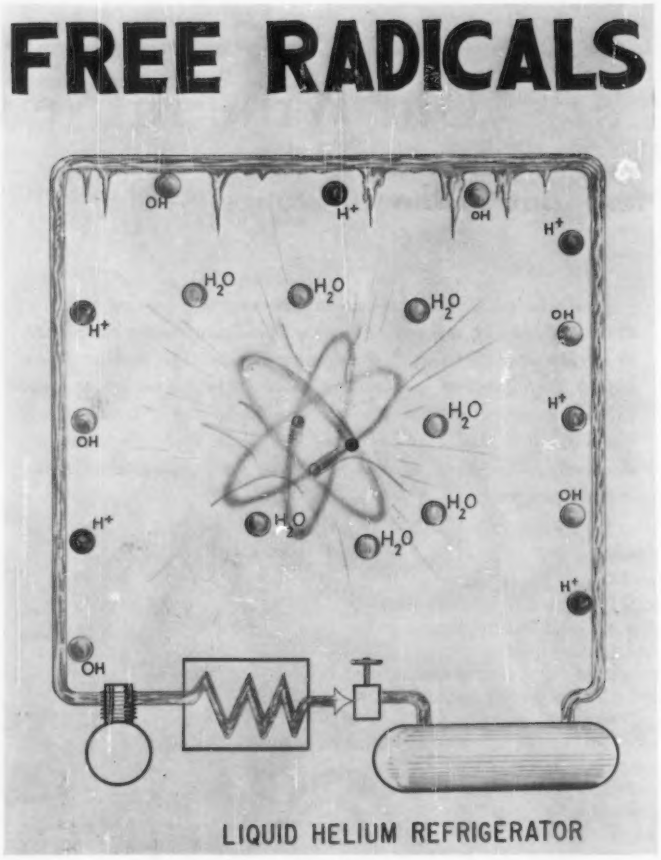

Fig. 3.

Even many water contaminants are destined to become blessings instead of burdens. The ocean is the master vault of many minerals, and dividends are accumulating with time. For example, one oceanographer estimates that the concentration of aluminum in the sea will double in the next thousand years. How long it will be before it is profitable to process 1000 tons of sea water to obtain three grams of tin, no one can say. However, it is reasonably certain that men soon will be extracting the stores of manganese-rich nodules deposited on the ocean bottoms.

It's in the Stars

Despite the fairy-tale flavor of this excursion through the looking glass, it is safe to say the water carnival hasn't even started. Space-age technology is demanding more and more power and obtaining fewer and fewer miles per calorie. One day, present conventional sources of power will be depleted, and nuclear fission, by that time, may be an impracticable means of supplying the demand. Nuclear fusion is the logical answer to this predicament. Considering mass relationships of earth substances, only the traces of deuterium and tritium, which occur in all natural waters, are suitable raw materials for a workable fusion process. The reaction $T^3 + D^2 = He^4 + n^1 + 17.6$ mev (million electron volts) could generate billions of Btu of energy per pound of water. The estimated 10^{17} lb of deuterium in the oceans thus could provide millions of times more energy than all fission sources put together.

The tritium-deuterium fusion is greatly complicated by the necessity of temperatures ranging from 45,000,000 to 100,000,000 C. To harness it, man must learn to confine the intense reaction, perhaps magnetically, as suggested in Fig. 4, and to withdraw its energy gradually instead of explosively. This will take a while, but when it is accomplished, water at last will provide us with an almost infinite source of energy—literally the energy of the stars.

Not Without Problems

Progress invariably causes problems, and water has created its share. The chloride stress-corrosion cracking threat in nuclear-powered, stainless-steel steam generators is a familiar example. Snow clogging of fuel lines and filters in jet aircraft by freeze-out of dissolved water at high altitudes is a less familiar, but equally troublesome, example. Conductivity problems in radar cooling systems due to traces of metallic impurities in the cooling water have caused headaches. Significant radioactive contamination of industrial and domestic water supplies is a definite possibility today, although it was scarcely heard of a few years ago. One can only guess what new problems may accompany further excursions in water technology.

Solution of these many problems involves development of a multitude of control tests and quality standards for which the fundamental research scientist has little time. Fortunately, technical groups like the ASTM have shouldered a large share of this responsibility. Committee D-19 on Industrial Water has arranged timely symposia to provide previews of problem areas and give its task groups flying starts at seeking solutions. New task groups, like those on radioactive aspects of water, have been created as necessary. This effort has yielded real dividends. ASTM's micro methods for dissolved oxygen and chloride ion played major roles in early studies of the stress-corrosion cracking problem. Its highly sensitive flame photometer method for sodium gave high-pressure boiler operators a new, effective tool for studying steam quality, and its ever up-to-date Manual on Industrial Water provides scientists, operators, and laymen with ready advice on many water problems. It is comforting to think that such active and effective groups will accompany the research scientist as he delves further into the secrets of water.

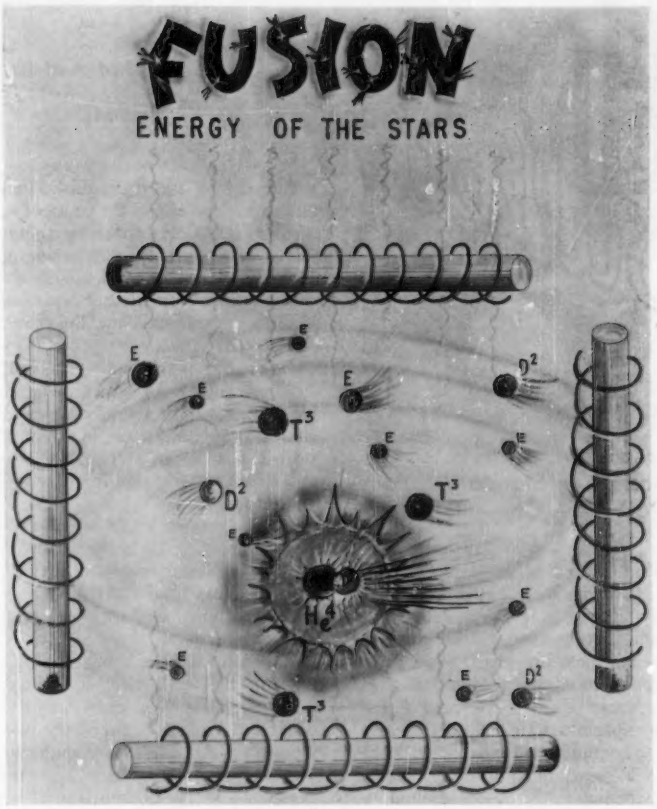

Fig. 4.

If history is any indication of the future, we can expect to find this ancient substance, water, in many new roles as science and technology advance with geometric strides—old wine in new bottles, to be sure. Each new use undoubtedly will become as commonplace as those we know today, and the problems associated with them probably will seem no more complex in retrospect. One can expect that each new problem will be attacked with the vigor and resourcefulness that always have characterized the field of water technology.

Three-Language Glossary of Plastics Terms Set

AN INTERNATIONAL standard that lists 800 equivalent plastics terms in English, French, and Russian is now completed, and its approval and publication by the International Organization for Standardization (ISO) is expected soon. This is one of a number of international standards in the field of plastics being considered by the member nations of ISO 61 on Plastics. These draft standards covering various test methods for determining properties of plastics were prepared by ISO 61, which met in Munich, Germany, October 26 to 31. Present were 112 delegates from 18 countries. Nine working groups held a total of 15 sessions and treated approximately 37 of the items currently listed on the committee's program of work.

The secretariat of the ISO committee is held by the United States through the American Standards Assn., USA member of ISO. The USA National Committee, which is a special subcommittee of ASTM Committee D-20 on Plastics, serves in an advisory capacity to ASA for the ISO plastics project. General chairman for the Munich meeting was Robert Burns, Materials Advisory Board, National Research Council; leader of the USA delegation is W. E. Brown, Dow Chemical Co.

One revised and three new draft ISO recommendations were approved by the committee at Munich. These drafts will now be submitted to all the ISO member countries for their approval. They are determination of the Vicat softening point; determination of the viscosity number of polyamide resins in solution; determination of the acetone soluble matter of phenolic molding materials; and determination of the thermal stability of poly(vinyl chloride) and related copolymers and their compounds by the discoloration method.

Out on letter ballot to ISO members are: method of test for tensile properties of plastics; determination of the maximum temperature and the time taken for temperature to rise during the setting of unsaturated polyester resins; determination of stiffness properties of plastics as a function of temperature by means of a torsion test; resistance of plastics to natural light; determination of changes in mechanical properties after contact with chemical substances; and resistance of plastics to artificial light.

Eight ISO recommendations for plastics have already been published, and 14 others are in final approval stages.

ASTM Bulletin

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Nineteen-Sixteen
Race Street
Philadelphia 3, Pa.

N. L. Mochel to Address Symposium on Standardization at 1960 AREA Convention

AT A SYMPOSIUM on standardization, March 14, 1960, to open the Annual Convention of the American Railway Engineering Assn., the keynoter and first speaker will be Norman L. Mochel, past-president of ASTM, and manager, metallurgical engineering, Westinghouse Electric Corp. Purpose of the symposium, to be held in Chicago, will be to acquaint railroad men with the benefits to be derived from increasing standardization in the design and manufacture of railroad equipment.

Mr. Mochel, who delivered the first Gillett Memorial Lecture in 1952, has rendered long and distinguished service to the Society and to the cause of standardization. Other speakers include:

J. S. Fair, general purchasing agent, Pennsylvania Railroad, will discuss opportunities for further standardization on the railroads and the economies that could result.

J. P. Kleinkort, manager, Railroad Products Div., American Brake Shoe Co., will speak of the advantages to be gained from greater use of standardization in the design and manufacture of trackwork (switches, frogs, crossings, guard rails, etc.)

R. H. Breeder, chief engineer, Santa Fe System, will discuss the opportunities for greater standardization of materials and products used by the engineering and maintenance-of-way departments of the railroads.

The symposium is being developed by AREA President F. R. Woolford, chief engineer, Western Pacific Railroad, and Executive Secretary Neal D. Howard. All ASTM members and committee members are welcome to attend. Further details concerning the symposium and the convention will be mailed to all members and committee members in the Chicago District.

25-Year ASTM Members, 1935–1960

Administracion Nacional de Combustibles, Alcohol y Portland
Australia, Commonwealth of, Director-General Posts and Telegraphs
Beard, Leslie C., Jr.
Better Fabrics Testing Bureau
Bigelow-Sanford Carpet Co., Inc.
Binder, Carl A.
Bridges, Frank R.
Bright, Harry A.
Britton, Leonard Alfred
Brown, George D.
Burton, H. H.
Bussow, Carl
California, University of, Library, College of Agriculture
Cannon Mills Co.
Carrier Corp.
Chicago, City of, Department of Streets and Sanitation
Detroit, City of, Department of Buildings and Safety
du Pont de Nemours and Co., Inc., E. I., Technical Library
Duvall, Charles S.
Freeman, John V.
Georgi, Carl W.
Glidden Co., The, Naval Stores Div.
Good Housekeeping Inst.
Gray, A. S.
Guitton, L.
Harrisson, Joseph W. E.
Humble Oil and Refining Co.
Johnson, J. F.
LaQue, Frank L.
Lewis, William H.
Louisiana Department of Highways
MacGregor, Charles W.
MacPherson, T. C. Harold
Manufacturers Standardization Society of the Valve and Fittings Industry
Maxwell, H. L.
Minnesota Mining and Manufacturing Co.
Mohasco Industries, Inc.
New York City Comptroller's Office
North Carolina State College, Engineering Research Dept.
Olsen, Tinius, 2nd
Oregon State College Library
Owens-Illinois Glass Co.
Parker, Norman A.
Partridge, Everett P.
Peerless Cement Corp.
Rhode Island School of Design, Textile School
Romig, O. E.
Roush, R. W.
Rummel, J. K.
Schoenborn, Edward M.
Schuster, Max
Screw and Bolt Corporation of America
Sirrine Co., J. E.
Sperry Gyroscope Co., Division of Sperry Rand Corp.
Steel Founders' Society of America
Trumbull Asphalt Co. of Delaware
Williams, Bruce
Worcester, City of, Department of Public Buildings
Wright, E. C.

MATERIAL QUESTIONS

Polystyrene Molding Materials

We have read with interest your specifications for polystyrene molding materials but we note that no reference is made to high-impact grades. We should be grateful if you can inform us of any existing specifications or any that are contemplated for the future.

Also, in note 3 of ASTM Method D256-56 (Impact Test for Plastics and Insulating Materials) it is stated that clamping pressure is important when testing polystyrene. Can you tell us whether this is important for high-impact materials?

● ASTM Committee D-20 on Plastics is developing specifications for rubber-modified polystyrene molding and extrusion compounds. The two major problems associated with formulating an acceptable specification are: (1) classifying the many commercial styrene-rubber products by type, and (2) attaining an acceptable and reproducible method of specimen preparation, particularly for the Izod impact test method, ASTM D 256. The first of these problems is now essentially resolved; but due to the nature of these materials, the latter presents an extremely complex problem. Because of anisotropy associated with injection molded specimens, it is necessary either to: (1) completely standardize the injection technique for specimen preparation, or (2) use virtually orientation-free specimens. Considerable progress is being made on the former, but standardization in the industry appears remote because of the expense of completely new instrumentation. The latter offers the best possibility for immediate action on the basis of compression moldings. Use of injection molded ½ by ½-in. bars is a possibility, but this would result in considerable delay because few in the industry have suitable molds.

With respect to your question regarding clamping pressure: experience with these materials indicates a clamping pressure of 10 in.-lb torque on the tightening screw of a standard machine of Baldwin-Lima-Hamilton design to be optimum. Deviation from this torque, particularly if on the low side, appears to lower reproducibility.

Automatic Coal Samplers

Will you please advise whether the (trade name) automatic coal sampler meets ASTM requirements?

● Although it is the policy of the Society not to rate commercial products, it would be, in any case, impossible to determine the effectiveness of a given coal sampling device without testing it under the actual sampling condition.

For methods of testing mechanical sampling equipment we can refer you to "Modern Practice in Design and Testing of Mechanical Coal Samplers," by R. L. Coryell and F. J. Schwerd, in *Power Engineering*, September 1958, p. 83. The Consolidated Edison Co. of New York has used these methods for years to ascertain whether the samples or subsamples are obtained within ASTM tolerances.

More on Pigs

Reaction to the article "A Pig Is a Pig Is a Pig," which appeared in the October ASTM BULLETIN, has been most heartening. It seems that Brobdingnagian prose is as universal as Sin, and as universally condemned. The following letter was especially pithy:

Editor:

Your recent piece interested me a great deal. As a former editor of a technical magazine, I have had some 20 years of experience in trying to make readable English out of the "juneque" that some technical chaps call writing.

I should like to amplify some of your thoughts about the reasons why so many technical people write poorly. Among academic people there is a sort of tradition that one must remain in the background and let his deeds speak for themselves. This requires third-person speaking and writing and complete omission of the first personal pronoun. I have been admonished in two universities for saying "I" when discussing publicly something I had been doing.

Another cause is that as students we must read a terrific amount of poorly written technical stuff. The masters of English prose of a few centuries ago were not hampered by the current need for telegraphic brevity that is imposed by the high cost of printing today. They could express themselves gracefully and fluently, and it is still a pleasure to read some of their writings.

Poor editing is another source of dull, though understandable English. A few years ago, I got the late Crosby Gaige to speak on a program of one of our technical societies. In contemporary times there has never been a man who could write more lucid and sparkling English than he. But when his talk was published in the Proceedings it was a drab collection of simple declarative sentences. He was understandably furious. The editor had taken all the sparkle and life out of his writing.

Still another cause of poor writing is the intellectual snobbery of a great many technical people who believe that anything that is easy to read and understand must be of no value. In my editorial days one of these chaps once told me that he would like to see some double integrals or other higher mathematics in our magazine. Without something requiring study on his part, he was inclined to regard the subject matter as trivia.

Prof. William Mansfield Clark of Johns Hopkins University once told an audience that "Mankind is given to minimize his troubles by using big words for little ones." I like this view better than the idea that the big word is used to impress others.

People in England speak more correctly and write much better than their opposite numbers in the United States. I had the opportunity to study this phenomenon in Britain when I was over there for seven months in the latter part of the War. I observed that parents in the better educated classes were very insistent on correct English usage by their children and drilled them over and over again until pronunciation and grammar were correct. We lack such home training in this country.

And finally, there is something in our manners and customs that impedes anyone who is trying to speak or write well, especially the former. Our compatriots do not want us to excel. It takes a strong man to withstand the ridicule of one's peers.

LAURENCE V. BURTON
Scarsdale, N. Y.

Schedule of ASTM Meetings

This gives the lastest information available at ASTM Headquarters. Direct mail notices of all district and committee meetings customarily distributed by the officers of the respective groups should be the final source of information on dates and location of meetings. This schedule does not attempt to list all meetings of smaller sections and subgroups.

Date	Committee	Place
Jan. 31–Feb. 5	Committee D-2 on Petroleum Products and Lubricants	Detroit, Mich. (Statler Hotel)
Feb. 1–5	**Committee Week**	**Chicago, Ill. (Sherman Hotel)**
Feb. 9	Southwest District	Houston, Tex.
Feb. 9–10	Committee B-5 on Copper and Copper Alloys, Cast and Wrought	Philadelphia, Pa. (Sheraton Hotel)
Feb. 11	Southwest District	Dallas, Tex.
Feb. 15–17	Committee D-1 on Paint, Varnish, Lacquer and Related Products	Washington, D. C. (Shoreham Hotel)
Feb. 16	Committee C-17 on Asbestos-Cement Products	New York, N. Y. (Universal Atlas Cement Co.)
Feb. 22–24	Committee D-27 on Electrical Insulating Liquids and Gases	Washington, D. C. (Shoreham Hotel)
Feb. 22–25	Joint ASTM-TAPPI Committee on Petroleum Wax	New York, N. Y. (Commodore Hotel)
Feb. 23–24	Committee B-4 on Metallic Materials for Thermostats and for Electrical Resistance, Heating, and Contacts	Washington, D. C. (Sheraton-Park Hotel)
Feb. 25–26	Committee C-3 on Chemical Resistant Mortars	Cleveland, Ohio (Hopkins Airport Motor Hotel)
Feb. 25–26	Committee F-1 on Materials for Electron Tubes and Semiconductor Devices	Washington, D. C. (Sheraton-Park Hotel)
March 1	Committee E-13 an Absorption Spectroscopy	Pittsburgh, Pa.
March 1–4	Committee D-13 on Textile Materials	New York, N. Y. (Sheraton-McAlpin Hotel)
March 7–9	Committee D-9 on Electrical Insulating Materials	Cincinnati, Ohio (Netherland-Hilton Hotel)
March 8–11	Committee D-20 on Plastics	Cincinnati, Ohio (Netherland-Hilton Hotel)
March 9–11	Committee C-16 on Thermal Insulating Materials	Charleston, S. C. (Hotel Fort Sumter)
March 31–April 1	Committee D-14 on Adhesives	Philadelphia, Pa. (Sheraton Hotel)
April 4–5	Committee D-10 Shipping Containers	Atlantic City, N. J.
April 6–7	Committee F-2 on Flexible Barrier Materials	Atlantic City, N. J.
April 19	Western New York District	Buffalo, N. Y.
April 26	Detroit District	Detroit, Mich.
June 16–17	Committee F-1 on Materials for Electron Tubes and Semiconductor Devices	Boston, Mass. (Statler Hotel)
June 26–July 1	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**

Error on Yellow Sticker for B 306 – 58

If you have yellow stickers for the 1959 Supplement to the 1958 Book of ASTM Standards, Part 2, please make the following correction on the sticker for Specification B 306 – 58: Change the tolerance "0.0001 in." to read "0.001 in."

NEW ASTM PUBLICATIONS

Supplements to Book of Standards: All 10 Parts Now off Press

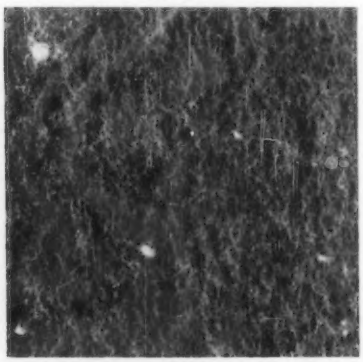
The 1959 Supplements to the 1958 Book of Standards are being published in ten parts in heavy paper covers. Their 2700 pages include the new and revised standards and tentatives adopted or accepted at the 62nd Annual Meeting or by the Administrative Committee on Standards. All but two Parts have been mailed. Parts 5 and 9 are being completed as this BULLETIN goes to press.

The ten parts are:

Part 1—Ferrous Metals (Specifications)
Part 2—Non-Ferrous Metals (Specifications), Electronic Materials
Part 3—Methods of Testing Metals (Except Chemical Analysis)
Part 4—Cement, Concrete, Mortars, Road Materials, Waterproofing, Soils
Part 5—Masonry Products, Ceramics, Thermal Insulation, Acoustical Materials, Sandwich and Building Constructions, Fire Tests
Part 6—Wood, Paper, Adhesives, Shipping Containers, Cellulose, Leather
Part 7—Petroleum Products, Lubricants, Tank Measurements, Engine Tests
Part 8—Paint, Naval Stores, Aromatic Hydrocarbons, Coal and Coke, Gaseous Fuels, Engine Antifreezes
Part 9—Plastics, Electrical Insulation, Rubber, Carbon Black
Part 10—Textiles, Soap, Water, Atmospheric Analysis, Wax Polishes

Comparison Standard for Neps in Cotton Fibers

A NEW ASTM reference standard for use in classifying neps in cotton fibers has just been completed by Committee D-13 on Textile Materials. In the ASTM Method of Test for Number of Neps in Cotton Fibers (D 1446), with which this comparison standard is to be used, neps are defined as "one or more fibers occurring in a tangled and unorganized mass."



NEPS IN COTTON FIBERS (WHITE DOTS)

The standard is a positive film photograph of natural size for use in determining the size classes of neps in cotton specimens. The unknown, or test, specimen of cotton lint is compared with the film over an illuminated viewing box having a ground-glass top. The nep standard measures 8½ by 11 in. and is enclosed in a plastic envelope. Single copies are $6.00, with a 15 per cent discount offered on orders for ten or more. Postage will be added to foreign shipments.

Bituminous Paving Materials—Including:

Symposium on Methods of Test for Design of Bituminous Paving Mixtures, Symposium on Practical and Statistical Significance of Tests and Properties of Bituminous Binders, Session on Road Paving Materials

AS A RESULT of expanded highway programs to accommodate our growing traffic load and increased airport runway construction to meet the needs of the growing air traffic of the jet age, there has been increased emphasis on better pavement construction. Highway engineers want to know more about factors entering into the design of more durable pavements. They also want to know more about the application of existing methods of test to design and construction of bituminous paving mixtures as well as the development of new tests for use in this field.

This volume, then, includes papers from two symposia and a technical session. The compendium is designed to give the engineer as well as others concerned with highway and runway construction an insight into current thinking. A variety of papers attack the problems which beset engineers and designers working in this field. The reader will find the volume well documented and illustrated. Included are:

Symposium on Methods of Test for Design of Bituminous Paving Mixtures

General Factors in Design of Bituminous Paving Mixtures—L. F. Rader

Theory and Application of a Gyratory Testing Machine for Hot-Mix Bituminous Pavement—John L. McRae and Charles R. Foster

Application of the Marshall Method to Hot-Mix Design—H. L. Lehmann and Verdi Adam

Control of Bituminous Shoulder Construction for the Northern Illinois Toll Highway—Joseph J. Waddell

Triaxial Testing of Bituminous Mixtures—W. H. Goetz and J. H. Schaub

Correlation of Hveem Stabilometer and Cohesiometer Test Results and Kneading Compactor Densities with Service Records of Bituminous Pavements—C. E. Minor

Void Requirements for Dense-Graded Bituminous Paving Mixtures—N. W. McLeod

Use of the Immersion-Compression Test in Evaluating and Designing Bituminous Paving Mixtures—Joseph F. Goode

Symposium on Practical and Statistical Significance of Tests and Properties of Bituminous Binders

Introduction—D. F. Fink

The Evolution of ASTM Tests and Specifications for Asphaltic Paving Materials—Gene Abson

Practical Significance of Tests on Asphalt Cements—N. W. McLeod

Precision of Present ASTM Tests on Bitumens and Bituminous Materials—A. B. Brown

Fundamental Statistical Concepts in Testing—P. E. Irick

Summary—Possibilities for Extension and Improvement of ASTM Tests on Bituminous Paving Binders—D. F. Fink

Papers on Road and Paving Materials

Fundamental Viscosity

Verens Saybolt Furol Refinery Control of Cut-back Asphalt—D. F. Levy, F. E. Fassnacht, R. D. Umbach, G. P. Hibler and D. W. Gagle

Density Changes in Asphalt Pavement Core Samples—T. C. Hein and R. J. Schmidt

STP 252; 238 pages, hard cover, price $5.50, to members $4.40.

Metallic Coated Iron and Steel Products

Compilation of Standards, A-5

THIS second edition of the A-5 compilation is a nearly complete revision of the first edition issued in 1956. Of the 34 standards included, all but 5 have been newly added, revised, or changed in status.

Among the materials covered are zinc-coated wire, strands, fencing, sheets, pipe, and hardware. Also included are aluminum-coated wire and aluminum-coated iron and steel articles as well as terne-alloy-coated sheets. There are 25 specifications, 6 methods of test, and 3 recommended practices.

Engineers and scientists concerned with coated metallic products, corrosion, and maintenance will find this compilation useful in their work.

ASTM Standards on Metallic Coated Iron and Steel Products, 176 pages, hard cover, price $3.50, to members $2.80.

Symposium on Identification of Water-Formed Deposits

SINCE THE most recent symposium on this subject in 1947, X-ray diffraction methods have been much improved by the use of the diffractometer, semiquantitative spectrographic methods have been developed and applied, and a number of newer analytical techniques have been brought to bear on the deposit problem. This symposium describes the usefulness of these analytical tools in determining the nature of deposits, starting with a statement of the problem from the standpoint of the water-treatment engineer. Then follow methods of elemental analysis (excluding wet chemical), phase identification, the study of thin corrosion films on steel, and finally the correlation of elemental analysis with phase identification, using the techniques employed for many years by the mineralogist.

This Symposium on Identification of Water-Formed Deposits offers the water-treatment engineer a wide range of analytical techniques for the identification of deposits in water systems, with discussion of the advantages and disadvantages of each method. Papers included are:

Introduction—R. K. Scott
Deposit Identification—First Step Toward Understanding a Water Problem—J. K. Rice
The Application of Emission Spectroscopy to the Analysis of Water-Formed Deposits—Charles H. Anderson
Identification by Instrumental Methods of Chemical Compounds in Water-Formed Deposits—C. M. Maddin and R. B. Rosene
Electron Microscopy and Electron Diffraction Studies of Oxide Films Formed on Iron in Water and Oxygen Atmospheres—Earl A. Gulbransen and Thomas P. Copan
Correlation of Elemental Analysis and Phase Identification as Viewed by a Mineralogist—J. V. Smith
Summary—R. K. Scott

STP 256; 80 pages, hard cover, price $2.75, to numbers $2.20.

Papers to Appear in Future Issues of the ASTM Bulletin

A Critical Review of Methods for Determining Hardness, Abrasion, and Wear Resistance of Plastics—L. Boor, Philadelphia Quartermaster Depot.
A Study of Rheological Testing of Elastomers at Low Temperatures, Part II—L. Boor, Philadelphia Quartermaster Depot, M. Hanok, New York Naval Shipyard, F. S. Conant, Firestone Tire and Rubber Co., and W. E. Scoville, Jr., Boston Woven Hose and Rubber Co.
Measurement of Environmental Stress Cracking of Polyethylene—A. Rudin and A. M. Birks, Canadian Industries, Ltd.
Measurement of the Brittleness Temperature of Polyethylene—A. M. Birks and A. Rudin, Canadian Industries, Ltd.
The Gravimetric Determination of Strontium Oxide in Portland Cement—C. L. Ford, Portland Cement Assn.
Movement of Sodium with Water in Neat Portland Cement—R. C. Hall and J. M. Rhodes, Kansas State University.
Design of Metallurgical Laboratory Equipment for Processing and Testing of Reactive and Refractory Metals—A. L. Feild, Jr., and V. A. Peckham, Jr., Universal-Cyclops Steel Corp.
An Instrument for the Determination of Impact Sensitivity of Materials in Contact with Liquid Oxygen—W. R. Lucas and W. A. Riehl, Army Ballistic Missile Agency, Redstone Arsenal.
A Reliable Technique for Measuring Brush Wear in an Atmosphere Containing Silicon Vapor—J. S. Axleson and F. M. Precopio, General Electric Co.
Improved NBS Abrasive Jet Method for Measuring Abrasion Resistance of Coatings—A. F. Roberts, National Bureau of Standards.
Tests for Potential and Past Moisture Expansion of Ceramic Building Units—E. H. Waters, J. S. Hosking and H. V. Hueber, Commonwealth Scientific and Industrial Research Organization of Australia.

Atmospheric Sampling and Analysis

Compilation of Standards, D-22

IN RECENT years there has developed a tremendous interest in the air around us. The expression "free as air" has often led many to believe that air was to be taken for granted.

Contamination of air resources has led engineers, scientists, and other technologists to re-evaluate "free air" not only from the industrial point of view but also from the health and safety standpoint.

In recognition of the need for standardized definitions and sampling and analytical procedures, ASTM organized its Committee D-22 on Atmospheric Sampling and Analysis. As a result of the committee's work the first complete compilation of the standards on atmospheric sampling and analysis is now made available. There are twelve standards including two recommended practices, nine methods of test, and one on definitions. They are:

Test for Concentration of Odorous Vapors—(Adsorption Method)
Methods for Continuous Analysis and Automatic Recording of the Sulfur Dioxide Content of the Atmosphere
Def. of Terms Relating to Atmospheric Sampling and Analysis
Rec. Practice for Planning the Sampling of the Atmosphere
Method for Measurement of Odor in Atmospheres—(Dilution Method)
Rec. Practices for Sampling Atmospheres for Analysis of Gases and Vapors
Test for Inorganic Fluoride in the Atmosphere
Test for Nitrogen Dioxide and Nitric Oxide Content of the Atmosphere—(Modified Griess-Ilosway Reaction)
Test for Oxides of Nitrogen in Gaseous Combustion Products—(Phenol-Disulfonic Acid Procedure)
Test for Oxidant (Ozone) Content of the Atmosphere
Test for Particular Matter in the Atmosphere (Optical Density of Filtered Deposit)
Test for Odor in Industrial Water and Industrial Waste Water

ASTM Standards on Methods of Atmospheric Sampling and Analysis, 116 pages, hard cover, price $2.25, to members $1.80.

1959 Year Book Mailed

Retain Your 1958 Book for List of Subcommittee Personnel

THE 736-PAGE 1959 Year Book, listing our 10,000 members alphabetically and geographically, and also listing our committee personnel, was mailed in December to all those who returned their request blanks. If you returned your request blank and have not received your Year Book, please advise ASTM Headquarters.

Subcommittee personnel in even years only

On instruction of the Board of Directors, the complete personnel of subcommittees will be published every other year—in the even-numbered years. The Year Book in odd-numbered years will contain only a list of subcommittees and their chairmen after the complete list of main committee personnel. Therefore, those interested in subcommittee personnel should retain their 1958 Year Books.

Geographic listing in odd years only

We have also been instructed to include the geographic listing of members every other year—in the odd-numbered years. It is therefore suggested that this section of the 1959 Year Book be retained until the 1961 Year Book becomes available.

Color Code Standard for Thermal Stability of Aviation Turbine Fuels

A NEW ASTM Color Standard for measuring high-temperature stability of jet fuels is now available. The new standard is used in conjunction with the Method of Test for Thermal Stability of Aviation Turbine Fuels (D 1660). This method describes a procedure for rating the tendencies of aviation gas-turbine fuels to deposit decomposition products in the fuel-system components of high-performance engines. The deposits are graded according to their color. The method is the result of research studies by the Coordinating Research Council. A set of five aluminum strips enclosed in a plastic case is available for $25.00. A 15 per cent discount is offered on orders for ten or more copies. Postage is added on foreign shipments.

Data Sheets.—For recording and plotting results of the ASTM-CFR Fuel Coker tests, data sheets are now available in pads of 50. The sheets are 8½ by 11 in., printed on durable thin paper suitable for reproduction by blueprint, multilithograph, or similar processes. Single pads $1.75, three pads $4.25.

Visual Aids for Standardizing and Communicating Product Appearance

THIS SYMPOSIUM was organized to focus attention on the problem of product appearance specification. In today's world the rapid communication of technological advances and the astonishing and almost universal increase in technological ability have made it difficult for a product to maintain a sales advantage on the basis of engineering design alone. A good machine may be equalled or improved upon by a competitor in a short period of time. Appeal and sales advantage must also depend on a high level of product appearance. While some aspects of this problem belong to the industrial designer, a portion of it falls within the areas of concern to engineers.

It is hoped that, with this area of activity now being spotlighted, some feedback of other ideas and techniques will develop. Papers included are:

Introduction—J. M. Hemphill
Status of ASTM Methods and Standards for Appearance Evaluation—I. Nimeroff
Visual Aids in the Textile Industry—J. B. Goldberg
Potential Uses of Closed Circuit Television for Product Inspection—R. Vendeland
Summary—G. W. Ingle

STP 258; 29 pages, paper cover, price $2.00, to members $1.60.

Copper and Copper Alloys

Compilation of Standards, B-5

THIS COMPILATION contains 137 standards, of which 17 are new, revised, or changed in status since the previous edition in 1957. In addition to standards for cast and wrought copper and copper alloys, the book contains some material on non-ferrous materials for electrical conductors and certain selected specifications on non-ferrous metals and alloys for primary forms of copper, zinc, lead, and nickel used in copper-alloy products. Some typical standards included are:

Spec. for Seamless Copper Boiler Tubes
Spec. for Hot-Rolled Copper Rods for Electrical Purposes
Spec. for Copper-Silicon Alloy Rod, Bar, and Shapes
Spec. for Leaded Brass Plate, Sheet, Strip, and Rolled Bar
Spec. for Leaded Yellow Brass Sand Castings for General Purposes
Spec. for Cored, Annular, Concentric-Lay-Stranded Copper Conductors
Spec. for Seamless Copper Tube for Refrigeration Field Service
Method of Mercurous Nitrate Test for Copper and Copper Alloys
Recommended Practices for Designating Significant Places in Specified Limiting Values (Tentative)
Sampling Wrought Non-Ferrous Metals and Alloys for Determination of Chemical Composition

ASTM Standards on Copper and Copper Alloys, 712 pages, hard cover, price $7.50, to members $6.

Symposium on Electroless Nickel Plating

THIS SYMPOSIUM is an attempt to gather all of the known useful information about "electroless nickel" plating under one cover. The need for this publication became evident a few years ago when a task group under ASTM Committee B-8 on Electrodeposited Metallic Coatings investigated the desirability of publishing a specification for "electroless nickel" plating. It was apparent that a survey of the current knowledge in this field would have to be made before serious work on specifications could be attempted.

The information collected by the group evoked such interest that it was decided to make it available for both technicians and scientists in the field. This information should be of particular value to those who are not yet acquainted with this process, its advantages, and production problems. The contents include:

History of the Electroless Plating Process—Abner Brenner
Chemical Reactions—Gregoire Gutzeit
Characteristics of Deposits—W. H. Metzger, Jr.
Processing Procedures—Abraham Krieg
Advantages and Limitations—E. B. Saubestre
Applications—W. H. Safranek
Test Methods—Bennie Cohen
Patent Situation—Gregoire Gutzeit
Bibliography of References—C. F. Waite

STP 265, 74 pages, hard cover, price $2.50, to members $2.

The Engineering Index: The Technical Man's Yellow Pages

JAMES R. KILLIAN, Jr., chairman of the President's Scientific Advisory Committee, has said that "science and engineering are largely built on the published record of earlier work done throughout the world." To the scientist or engineer who wishes to build, however, the body of that published record is growing at an appalling rate. About 55,000 journals appear annually, containing about 1,200,000 articles in some branch of engineering or science. In addition, more than 60,000 books are published every year, and about 100,000 research reports are written for only a very limited audience.

One agency that has been coping with this rising flood of information since 1885 is the Engineering Index. This nonprofit organization employs a staff of qualified editors who review, abstract, and index more than 1500 periodicals and society transactions, as well as large numbers of bulletins and reports of government bureaus, schools, and research organizations. The literature abstracted originates in 44 countries and is published in 22 languages in addition to English.

Subscribers to the complete indexing service receive abstracts daily, on 3 by 5-in. cards—about 30,000 per year. Or a subscriber may request abstracts only in one or more "field of interest" divisions, in which case he receives his abstracts weekly. All publications reviewed are filed permanently in the Engineering Societies Library. The library, which is open to the public, supplies, at minimum cost, photoprints, microfilm copies, and translations of the complete text of any article abstracted by the Engineering Index. At the end of each year, the information on that year's accumulation of index cards is compiled and published in a bound volume.

The long list of subscribers to the index includes libraries, industrial firms, trade associations, government agencies, colleges and universities, research institutes, and individuals—in short, persons or organizations who have a stake in knowing what is going on throughout the world of technology. The Engineering Index, in its 75th year, stands unrivaled today as the authentic guide to the periodical technical literature.

Actions on Standards

THE ADMINISTRATIVE COMMITTEE ON STANDARDS is empowered to pass on proposed new tentatives, revisions of existing tentatives, tentative revisions of standards, and withdrawal of standards and tentatives offered between Annual Meetings of the Society. On November 23, 1959 the Standards Committee took the following actions. Anyone interested in securing copies of the standards should write to Headquarters regarding their availability.

Electrical Insulating Materials

Tentative Methods of Testing Nonrigid Vinyl Chloride Polymer Tubing (D 876 – 58 T).

Revision.—Definitions and significance statements have been added for brittleness temperature and resistance to penetration.

Standard Methods of Testing Electrical Porcelain (D 116 – 44).

Revision and Reversion to Tentative.—Numerous changes have been made in order to bring the method up to date.

Standard Methods of Test for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies (D 149 – 59).

Tentative Revision.—This tentative revision consists of a new Appendix I on Significance of the Dielectric Strength Test which is considered more up to date than the present Appendix I. Section 2 has been changed to provide a formal definition of dielectric breakdown voltage and to restate the definition of dielectric strength in terms of breakdown voltage and thickness. Dielectric breakdown voltage appears in the title of the methods but until now no formal definition of the term has been stated in the methods.

Standard Methods of Testing Sheet and Plate Materials Used for Electrical Insulation (D 229 – 58).

Tentative Revision.—Sections 27(*c*), 29, and 30 have been changed to remove or reduce the problem of flashover when breakdown voltage tests are performed parallel to the flat sides of sheets using tapered-pin electrodes.

Standard Methods of Test for Electrical Resistance of Insulating Materials (D 257 – 58).

Tentative Revision.—Section 4 on General Procedures has been revised in order to give greater emphasis to importance of performing tests with specimens in conditioning atmosphere; a new Section 3 has been added to give emphasis to possible effects of time of electrification and applied voltage; and Appendix I has been revised to bring effective area corrections up to date and to state them in more readily usable form.

Standard Specifications or Communication and Signal Lime-Glass Insulators (D 879 – 58).

Tentative Revision.—Various changes have been made to clarify the specifications and bring them up to date.

Rubber and Rubber-Like Materials

Tentative Specification for Low Voltage Insulating Gloves (D 1700 – 59 T).

New Tentative.—These specifications cover rubber insulating gloves used for protection of electrical workers from electric shock while working on energized conductors or equipment. These gloves are designated as Class O-Proof Test 5000 v, 3 min, and are intended to be used only on voltages less than 750 v.

Tentative Method of Test for Viscosity and Curing Characteristics of Rubber by the Shearing Disk Viscometer (D 1646 – 59 T).

New Tentative.—This method describes the procedure for use of the shearing disk viscometer when applied to rubber or other elastomeric materials. It may be used as a standard method for determining the viscosity of such materials in the raw or compounded state, and for determining the curing characteristics of vulcanizable compounds. The method combines Methods D 927 and D 1077 into one standard with revisions, and these two methods have been withdrawn as indicated below.

Tentative Specifications for Rubber Insulating Gloves (D 120 – 52 T).

Revision.—The revisions bring the specification up to date with modern terminology and refinements.

Tentative Methods of Sample Preparation for Physical Testing of Rubber Products (D 15 – 59 T).

Revision.—Styrene-butadiene rubber, type 1509, has been added to Table II, column 2B.

Standard Specification for Ozone Resisting Insulation for Wire and Cable (D 574 – 58).

Revision and Reversion to Tentative.—Sections 3(*b*), (*c*), and (*e*) have been revised in order to bring the specification up to date.

Tentative Methods of Testing Rubber Coated Fabrics (D 751 – 57 T).

Revision.—Sections 37 and 39 have been revised, and there has been added a new Section 40 covering the tensile testing of coated fabrics.

Tentative Specification and Methods of Test for Latex Foam Rubbers (D 1055 – 58 T).

Revision.—The revision is intended to improve the nomenclature symbols and to make the compression values meaningful in line with the grade numbers. Also revised is the method of expressing compression set.

Tentative Recommended Practice for Description of Types of Styrene-Butadiene Rubbers (D 1419 – 59 T).

Revision.—Committee D-11 has assigned the number SBR-1509 to a new synthetic rubber, and the revision provides for the addition of the description of the rubber to Table II.

Tentative Specifications and Methods of Test for Flexible Urethane Foam (D 1564 – 58 T).

Revision.—The nomenclature and grade numbers have been revised in order that the compression indentation values will have more significance. A method for ball rebound resilience tests has been added.

Tentative Specifications and Methods of Test for Flexible Foams Made from Polymers or Copolymers of Vinyl Chloride (D 1565 – 58 T).

Revision.—The revision comprises revised nomenclature and grade numbers significant with indentation values.

Tentative Specifications and Methods of Test for Sponge and Expanded Cellular Rubber Products (D 1056 – 58 T).

Revision.—The nomenclature, grade numbers, and method for determining water absorption have been revised.

Standard Methods of Testing Adhesives for Brake Lining and Other Friction Materials (D 1205 – 58).

Revision and Reversion to Tentative.—There has been added a method for nondestructive testing for defective bond areas, primarily for brake lining, making use of an ultrasonic testing instrument.

Tentative Method of Test for Viscosity of Rubber and Rubber-like Materials by the Shearing Disk Viscometer (D 927 – 57 T).

Tentative Method of Test for Cure Characteristics of Vulcanizable Rubber Mixtures During Heating by the Shearing Disk Viscometer (D 1077 – 55 T).

Withdrawal.—These methods have been replaced by the new Tentative Method of Test for Viscosity and Curing Characteristics of Rubber by the Shearing Disk Viscometer (D 1646 – 59 T), referred to above.

Plastics

Tentative Method of Test for Indentation Hardness of Plastics by Means of a Durometer (D 1706 – 59 T).

New Tentative.—This method covers a procedure for determining the indentation hardness of rigid, semirigid, and nonrigid plastics by means of a durometer. The results obtained by this method are a measure of the indentation into the plastic material of the indenter under load.

1960 Annual Meeting—A Preview

SEVEN SYMPOSIA and five special sessions are planned for the 1960 Annual Meeting to be held at the Chalfonte-Haddon Hall in Atlantic City, N. J., the week of June 26 to July 1. Additional sessions comprising the independent offers received will also be scheduled, but it is too early to say what these topics will be. The April issue of the ASTM BULLETIN will carry the complete detailed program of the meeting. A partial preview of symposia and sessions follows:

Symposia

Present Methods of Metallographic Specimen Preparation
Sponsored by Committee E-4 on Metallography

Shear Testing
Sponsored by Subcommittee XXV on Shear and Torsion Tests of Committee E-1 on Methods of Testing

Radiation Effects and Radiation Dosimetry
Sponsored by Committee E-10 on Radioisotopes and Radiation Effects

Nuclear Methods for Measuring Soil Density and Moisture
Sponsored by Committee D-18 on Soils for Engineering Purposes

Recent Progress in Materials Science

Nature and Origin of Strength of Materials
Both Sponsored by the Division on Materials Sciences

Quality of Observations
Sponsored jointly by the Administrative Committee on Research and Committee E-11 on Quality Control of Materials

Sessions

Concrete and Concrete Aggregates
Sponsored by Committee C-9 on Concrete and Concrete Aggregates

Road and Paving Materials
Sponsored by Committee D-4 on Road and Paving Materials

Soils
Sponsored by Committee D-18 on Soils for Engineering Purposes

Sonic Fatigue
Sponsored by Committee E-9 on Fatigue

Low-Temperature Properties of High-Strength Aircraft and Missile Materials Sponsored by Joint Committee on Effect of Temperature on the Properties of Metals

Apparatus Exhibit

The biennial ASTM Apparatus Exhibit will be an important feature of the meeting. At booths in the Vernon Room and in the English Lounge of Haddon Hall, manufacturers and distributors will display the latest models of a wide variety of testing apparatus and laboratory supplies for most of the areas of ASTM activity. Here will be an opportunity to see the newest developments in one's own field of activity and to browse through displays of apparatus for related fields. The exhibit is one of the Society's best opportunities for achieving that "cross pollination" of ideas so often spoken of in top planning conferences but so seldom found in everyday experience.

Photographic Exhibit

The always-popular Photographic Exhibit will be on display in an area adjacent to the Apparatus Exhibit. Here one may find the best of our members' efforts in technical photography. On display will be photographs illustrating apparatus, instruments, processing and testing techniques, and standards. A large section will be devoted to photomicrographs and electron micrographs dealing with all kinds of materials in magnifications up to 50,000×. A special section will be devoted to student entries.

ISO Committee Urges Adoption of ASTM Sieve Designations

ISO TECHNICAL Committee TC 24/SC1 has voted to instruct the Secretariat to submit, as an ISO Recommendation for Test Sieves, a series of 14 sieves, comprising every other sieve listed in Table I of ASTM Specification E-11, from the $\frac{7}{8}$-in. size to the 44-micron (No. 325) size. This was reported by L. V. Judson, National Bureau of Standards, who headed the U. S. delegation at a meeting of the committee, Oct. 7–10, 1959, at The Hague, Netherlands.

The action taken by ASTM in modernizing the wire diameter specifications had made a profound and favorable impression on the other members of the committee, Mr. Judson reported. It appeared that the positive U. S. action taken in revising Specification E-11 was an important factor in arriving at a proposal that is fully compatible with the ASTM standard. The work on Specification E-11 has been in a committee of which L. T. Work, consulting engineer, is chairman, and Mr. Judson is secretary.

The committee also voted unanimously to express openings of sieves 1 mm and coarser in millimeters, and below 1 mm in microns. The U. S. delegation wholly approved this idea and feels that it should be adopted for the U. S. series.

ASTM National Meetings—1960–1964

(Members may wish to clip this for their files)

Year	Committee Week	Annual Meeting	Pacific Area National Meeting
1960	February 1–5 The Sherman Chicago, Ill.	June 26–July 1 Chalfonte-Haddon Hall Atlantic City, N. J. (With Exhibit)	None
1961	January 29–February 3 Netherland Hilton Hotel Cincinnati, Ohio	June 25–30 Chalfonte-Haddon Hall Atlantic City, N. J.	None
1962	February 5–9 The Statler Hilton Dallas, Tex.	June 24–29 Hotel Statler New York, N. Y. (With Exhibit)	September 30–October 5 Hotel Statler Los Angeles, Calif.
1963	February 3–8 Queen Elizabeth Hotel Montreal, Canada	June 23–28 Chalfonte-Haddon Hall Atlantic City, N. J.	None
1964	February 3–7 Sheraton Hotel Philadelphia Pa.	June 21–26 Conrad Hilton Hotel Chicago, Ill. (With Exhibit)	None

Participating member countries present at the meeting were France, Germany, India, Netherlands, United Kingdom, and the United States. Czechoslovakia, Poland, and the USSR were absent.

Air Pollution Research Projects Being Surveyed by ASME

THE AMERICAN SOCIETY of Mechanical Engineers will bring up to date its compilation of air pollution research projects active during 1959. Questionnaires were sent out in December 1959 to all organizations and individuals known to be active in the field. Other organizations and individuals who wish to be included should communicate with: Mr. Austin Heller, chairman, Task Group on Air Pollution Research, American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y.

From Certainty to Statistics*

By FRANK H. SQUIRES[1]

The author is a management consultant specializing in organization for reliability and quality control. His seventeen years in line management in the electronics and missile components industries plus his experience as a consultant have resulted in an acute appreciation of the effects of the new sciences of probability on traditionally oriented personnel.

A STATISTICAL approach is implicit in every testing problem. One is always confronted with the problem of how little testing can be done to learn as much as possible. However much that little may be short of 100 per cent, which would not be likely in any practical situation, the analyzed test data will give only an estimate of lot quality. Statistics are, therefore, inherent in testing problems and they tend to be taken for granted by the testing profession.

It seems to me we should give some thought to the question whether statistics are equally acceptable by the many in industry who are asked to believe the test results.

Statistics, for me, means the work of Walter Shewhart and his colleagues at Bell Telephone Laboratories in the late 1920's and through the 1930's. Most are familiar, I'm sure, with the basic texts they produced: Walter Shewhart's "Economic Control of Quality of Manufactured Product," published in 1931, and the Dodge-Romig Sampling Tables, which came out a short time later.

I have tried to recreate in my own mind the scene as it might have been in those quiet offices, a cloistered oasis in the years between the wars. One can imagine the excitement of those studious mathematicians as they pressed forward on their austere safari from the principle of imperfectibility, to the concept of inherent variability, to the development of techniques for the control of manufacturing processes within the limits of inherent variability. It has always seemed to me that this was an event of historic significance, sensed, I am sure, by the participating mathematicians, but not by the many in industry who were to feel its impact. A hurricane was generated in these quiet offices, its small and slowly accelerating vortex shifting gently from desk to desk before it gathered full momentum and burst upon the manufacturing world.

The results were remarkable. The mathematicians had reduced the work of years of study to some relatively simple techniques for measuring the limits of variability in any given process and for controlling within these limits thereafter. The statistical techniques and the methods of application were easy to understand for those who wanted to understand.

Fanatical supporters ranged themselves behind the $\bar{X}$ and R control charts. But they were faced by equally fierce opponents. Most remarkable was the fact that few were heard to say, "But of course, these statistical techniques are self-evidently good. Put them into operation without any delay." It seemed incredible that something as "cold," as detached as a set of statistical techniques should cause so much emotional excitement. One would have expected universal acclaim for a truly objective measure of quality, for a Solomon with a statistical sword.

At first glance, it appeared that the objections came from operators who resented having to learn a new technique. Objections were made by supervisors who had never had to face a quantitative measure of the quality of their work. They preferred the "judgment" of an inspector to the unimpassioned indications of a statistical chart. You know what "judgment" is? An inspector is exercising "judgment" when he decides that a piece is "good enough" if it is only half a thousandth outside the drawing tolerance limits, or if the deposit of cadmium plate is only 0.0002-in. thick instead of 0.0003-in., as the engineers have specified. I must emphasize that the exercise of "judgment" in this manner is motivated by a most sincere interest in the product. It is colored by the inspector's knowledge of many discrepancies accepted by the engineers in past reviews. Indeed, it should be recognized that every discrepancy accepted by the engineers disturbs the belief of inspectors and producers in the sanctity of the drawing tolerance limits, in the engineers' assertion that the tolerance limits are the maximum allowable.

The necessity to abandon the warmly subjective atmosphere of judgment and compromise in favor of the cold objectivity of statistical measures of quality was the basis for some opposition. Indeed, it remains so to this day. But it soon appeared that this was not all. Statistical measures of quality are concerned with the whole as distinct from the individual part; they appraise the individual part not because it is "itself"—something unique—but because it conforms to some average condition. The common habit for 2000 years in the Western World has been to hold those men and women the most valuable who were the most different. In like manner, those works of Man were thought the most valuable which were the most different and unusual.

But the statistician's highest praise goes to the pieces that are the most like each other, which are the most uniformly undistinguishable. The unpopularity of this statistical measure of worth is revealed in the common phrase "dull uniformity."

Imagine how annoyed you would be if the teacher reported, "Mrs. Jones, I hardly noticed your Johnny the whole term. He never varied much from the average."

Or consider that you have been denounced as "the most cruel, the meanest man alive." There is hope in this—you are still distinguished from a billion other men in the world, although you are now the worst, instead of the best of men. Such a rousing denunciation could easily turn into a declaration of love.

But imagine that she had said, "As a man, as a potential husband, you are substantially below the national average." Then you know you're through—you have been compared with others, you are no longer the best or worst of men, but only a deviate from a statistical average.

But, you might say, statistical measures of worth are concerned with inert materials, not people! This assumption crumbles when carefully examined. Fundamentally the inspector is appraising the ability of the producer who machined the part, or assembled the component.

Every test report is a comment on the chemist who compounded the material, as, for example, a new alloy; and on the process engineer who devised the process that produced, or failed to produce, a uniform consistency. At what could be called the second remove, there is the purchasing agent, who is quite capable of feeling that his ability to

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* Statistics Luncheon Address, Third Pacific Area National Meeting of ASTM, San Francisco, Calif., Oct. 12, 1959.

[1] Management Consultant, Los Angeles, Calif.

choose good sources of supply is challenged by an adverse report.

The irremovable tendency of the human individual to identify himself with the work of his brain or his hands, and the fact that individuals in the Western World are intensely individualistic and proud of those traits which make them "different," create an atmosphere, a cultural background, not compatible with statistical measures of worth.

But that is not all. Statistical measures of worth are approximations. They make no claim to certainty. They limit the area of doubt, but they cannot reduce the doubt to zero. A test report made on a sample of material is an estimate of the condition of the whole. A layman might ask, "What d'you mean an estimate?"

"Well, it's an approximation."

"D'you mean you're not certain?"

"Of course not. No one can be certain of anything."

"Oh, No!!"

Now, we know that there can be no absolute certainty in secular affairs, and certainly not in test reports on materials. You can embark on a long dissertation to convince the layman that the area of doubt can never be reduced to zero, that you know as much as you will ever know when the area of doubt has been reduced to its practicable minimum. Unfortunately, the layman is rarely convinced. You have accepted the concept of uncertainty, and he has not.

The shift from certainty to doubt has come upon us with shattering speed. Students were still being taught in the 1920's that the atom was the ultimate indestructible particle of matter, although Rutherford had split the atom in 1919. Starting from an indestructible particle which combines with other particles to form molecules in an exactly predictable manner one can develop a science of certainty. But when it was discovered that the indestructible particle was composed of a nucleus surrounded by electrons in orbit, and when it was further learned that the behavior of the orbiting electrons was not exactly predictable, then we were confronted with an utterly new world. Not new because the world about us had changed, but new because we now had to think about it in a fundamentally different manner. Henceforth, all measures of worth, of quality, would be statistical approximations, and certainty would give place to minimized doubt.

The destruction of 19th Century certainty and the evolution of a world in which statistical measures of worth are the only valid measures might still be of merely academic interest if it were not for one great problem. This is the reliability of missiles and space vehicles. Quantitative reliability is a prediction as to the probability that the missile will perform as required. It is essentially a statistical concept. A reliability program starts from a mathematical model and concludes with a statistical fact.

Complaints are multiplying in the public press about the poor reliability of missiles and space vehicles. Dr. Abe Silverstein, director of space flight development for the National Aeronautics and Space Administration, told an audience of scientists in San Diego, "Reliability of space vehicles is the greatest problem we face. Our reliability is poor."[2] He went on to give a rather horrifying account of various missile failures.

Mr. B. Bradford Ritchardson, of Northrop's Norair Division, said recently that "We must design for reliability with a furious and relentless determination."[3] Similar comments are multiplying in the popular press. Now, it is true that reliability has to be designed into the product, like any other quality characteristic. However, the production of a reliable missile is, to a large extent, a manufacturing problem. When the engineers and scientists have done their part, a product reliable enough to operate without a pilot can only be produced if all those concerned recognize that quantitative reliability is a statistical concept and that it can only be achieved by exact conformance to statistically determined tests on many materials and components.

The crucial point is that we have good reason to suspect that many persons concerned in the production of missiles and space vehicles and the thousands of parts that go into them are not convinced that the demonstration of reliability is a statistical problem. When one thinks of any missile failure and the ensuing investigation, one can speculate on how it might go. The investigators might ask the engineers which 5, or 55, or 155 components could possibly have contributed to the failure. An exhaustive inquiry into the manufacture of these components would most probably turn up an incompletely tested component or an insufficiently tested material. By incompletely and insufficiently I mean statistically inadequate. It might then be found that statistically adequate tests had not been specified, or if specified had not been completed.

To conclude, we must recognize a problem so vast that its correction will require a change in the cultural attitude of those concerned with the manufacture of missile and space vehicles. These Western Individualists must adjust their thinking to the profound changes taking place in science and engineering of which the most extreme is the change from certainty to statistics: they must learn to accept the relative uncertainty of the statistical approach and yet be convinced that this is the only valid road to reliable missiles and space vehicles.

[2] *U. S. News and World Report*, Aug. 3, 1959.

[3] *Los Angeles Times*, Oct. 8, 1959.

M.I.T. President Urges Interdisciplinary Research

In his annual report as president of M.I.T., released in October, Julius A. Stratton warns that engineering and science teachers "may be compelled to break with conventions of the past" in order "to teach difficult, basic subjects to larger groups of students."

Bold and creative thinking is needed about both the substance and the methods of instruction, Dr. Stratton argues, because three major forces "are working to make obsolete large segments of the traditional curricula and to outmode many of the methods of instruction." These are: (1) the stupendous accumulation of new knowledge and principles flowing from advances in every field of science and engineering; (2) the increasing importance of a thorough command of modern physics, chemistry, and mathematics; and (3) the rapid dissolution of the traditional boundaries between professional fields which has required that the foundations of a sound professional education constantly be broadened.

"There is no greater popular misapprehension about the nature of science than that it is built upon a fixed and permanent structure," says Dr. Stratton. "We should reexamine with an open mind the relative merits of the lecture, recitation, tutorial, and seminar methods, and we should be progressive in the use of every modern technique for the effective presentation of subject matter in classroom and laboratory."

Dr. Stratton foresees more crossing of lines between specialized fields, as is now taking place in several research centers at the Institute. In such centers, he believes, "we are beginning to see something of the future organization of a modern scientific university." "The most comprehensive of these plans" for interdisciplinary research "encompasses the field of materials. It is a field in which M.I.T. occupies a unique position. In no other academic institution is there so large and so strong a group in solid state science and materials engineering. Nearly 100 faculty members are active in this field. In all, over 500 people drawn from nine different departments, including graduate students, are participating in this work. Our annual budget for research in materials is now in excess of $4,000,000."

Fracture Testing of High-Strength Sheet Materials:

A Report of a Special ASTM Committee[1]

Editors Note.—The second and third chapters of this report and the conclusions will appear in the next issue of the ASTM BULLETIN.

THE REQUIREMENT of the minimum possible weight in solid-propellant rocket casings has led to the use of very-high-strength materials—for example, steels with yield strengths greater than 200,000 psi. At these high strength levels, many materials have been found to behave in a brittle manner in the presence of small flaws, which may be present in the material or may arise during fabrication of these thin-walled pressure vessels. As a result, service failure often occurs by brittle fracture rather than by yielding and distortion and at stresses well below the design stress, usually based on the yield strength of the material.

At present, there are no generally accepted and standardized tests for sheet materials capable of evaluating their resistance to brittle fracture, specifically the resistance of a sheet material to crack propagation. Early in 1959, at the suggestion of the U. S. Department of Defense, the ASTM organized an *ad hoc* committee[1] to review testing methods presently available and, ultimately, to recommend to the ASTM a standard method for evaluating high-strength sheet materials with respect to their resistance to brittle fracture. The committee has limited its attention to materials, both ferrous and non-ferrous, having a strength-to-density ratio of 700,000 (psi: lb per cu in.).

Early in the discussion of this problem, it became apparent that probably two types of tests would be required. It seemed highly desirable to have a method for measuring quantitatively the resistance to crack propagation of a sheet material in such a way that the result of this measurement could be used quantitatively to assist in the design of pressure vessels and in the analysis of service failures. Since the indications were that such a test method would probably be somewhat complex and time-consuming, there also appeared to be a need for a simpler and more rapid "screening" test, capable of qualitatively ranking many materials with respect to their resistance to brittle fracture.

In principle, there are two ways to prove a test method. With a large body of service performance data available—particularly service failure data—a correlation can be attempted between test result and service performance to determine if the test method is measuring the material characteristic that governs performance. In the absence of adequate service performance data, it may still be possible to establish a test method if a suitable method of analysis is available by which it may be shown that the test method is measuring the significant quantities governing performance and that the test result may be generalized to the more complex conditions existing in an actual structure. It is the view of the committee that, at present, the second approach must be taken with respect to high-strength sheet materials and, further, that the validity of the analytical methods of fracture mechanics is sufficiently well established to justify this approach.

The purposes of this interim report are (1) to inform the membership of the ASTM of the progress that has been made in formulating suitable test methods, (2) to stimulate additional investigation of the test methods described, (3) to invite the submission of additional data not yet available to the committee, and (4) to solicit comments on committee progress.

The report contains three major chapters.[2] The first deals with methods of testing to measure a material characteristic called "fracture toughness," the stress analysis underlying the test method, and the application of the test result to design and to failure analysis. The second chapter deals with the effect of temperature on fracture toughness for a number of typical materials. The third chapter describes three possible screening test methods that have been used in evaluating materials and methods of heat treatment, the limitations of each method, and the justification for considering each method. The report closes with tentative recommendations for a test method for evaluating fracture toughness quantitatively and for a test method for screening materials.

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[1] The ASTM Committee on Fracture Testing of High-Strength Sheet Materials is composed of the following members:

J. R. Low, Jr., Chairman, Research Laboratory, General Electric Co.
J. C. Barrett, Secretary, Office of the Director, Defense Research and Engineering
W. F. Brown, Jr., Lewis Research Center, National Aeronautics and Space Administration
D. K. Hanink, Allison Division, General Motors Corp.
R. H. Heyer, Armco Steel Corp.
G. R. Irwin, Naval Research Laboratory
L. D. Jaffe, Jet Propulsion Laboratory, California Institute of Technology
W. T. Lankford, Research Laboratory, United States Steel Co.
J. E. Srawley, Metallurgy Division, Naval Research Laboratory
L. L. Wyman, National Bureau of Standards

The committee acknowledges the valuable contributions of A. J. Brothers, J. E. Campbell, J. W. Caum, A. B. Goodwin, J. M. Hodge, J. M. Krafft, R. A. Rawe, G. R. Sippell, and B. M. Wundt who, while not members of the committee, have participated in many of its meetings.

[2] This is the first chapter of the report. The second and third chapters and the closing recommendations will be published in the ASTM BULLETIN issue of February, 1960.

COMMENTS SOLICITED: The ASTM committee writing this report invites the readers to submit comments for consideration. Additional data on this subject would be particularly appreciated. Such correspondence should be addressed to the ASTM Committee on Fracture Testing of High-Strength Sheet Materials, American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Fracture Testing and Fracture Analysis of Sharply-Notched Tension Sheet-Specimens to Measure Material Resistance to Crack Propagation

This chapter describes the evaluation of fracture toughness in terms quantitatively applicable to the analysis of service failures, or to the selection of materials, or to the design of components resistant to such failures. The procedures involve the tension testing of a sheet specimen containing sharp notches or initial cracks oriented normal to the applied tensile stress. Interpretation of these tests, although based on stress analyses, is readily carried out by graphical procedures.

The test method is described in the following manner: After the introductory comments of this chapter, the dimensions of the test specimens and the testing procedures are given under Test Specimens and Procedure. Included are comments on loading fixtures, techniques of notch finishing, and the use of a staining technique for direct measurement of slow crack extension. The section on Computation of K-Values then provides, without derivation, the analysis through which results of tests are expressed in terms of values of the fracture toughness K_c. The section on Practical Application of K_c-Values is a brief review of the significance of K_c-values when applied to fracture problems. The recommended testing and analysis procedures are based on extensive stress-analysis investigations including the approximate influence of localized plastic yielding (1).[3] A short outline of essential basic facts is given under Stress Analysis of Selected Tensile Specimens. The balance of these introductory comments establish the general viewpoint with regard to influences of crack length, crack propagation, and strain rate. The symbols used throughout this paper are explained in the Appendix.

For very brittle materials, the Griffith theory permits prediction of conditions for unstable crack propagation. Accordingly, a crack becomes unstable when, for a given increase in crack length, the energy decrease in the surrounding stress field exceeds the energy required to create the new crack-surface area. Failure of the Griffith theory to interpret fracture in less brittle materials suggested to Irwin (2) and to Orowan (3) that the surface energy should be augmented, or even replaced, by the work of plastic deformation in the volume of material adjacent to the crack tip. However, attempts to define and measure this plastic work revealed unanticipated complexity. The size of the plastic zone, and thus the inelastic energy it absorbs, was found to change with crack length and with specimen dimensions generally, as well as with the material. To measure the rate of energy absorption with crack growth is thus to measure a variable quantity, not a characteristic constant of material toughness.

This difficulty has been surmounted by (1) analyzing the locally elevated stress field that surrounds the crack and, for this reason, controls the crack extension process and by (2) stating the magnitude of the stress elevation for onset of rapid fracture. Inasmuch as the stresses are derivatives of the strain energy and inasmuch as, in the gross, the stress field is the reservoir of crack extension energy, this approach is equivalent to an energy analysis and thus closely related to the modified Griffith theory. Accordingly, when an elastic stress analysis of approximate validity can be applied, the Griffith theory strain energy-release rate can be estimated. However, it is not assumed, as in the modified Griffith theory, that the rate of energy dissipation with crack extension remains constant. The viewpoint taken here is more general. Stress analysis procedures are used descriptively to provide a simple, rational basis both for expressing crack toughness in quantitative terms and for relating it to such factors as section thickness, yield strength, temperature, and elastic constraint.

When sharply and deeply notched sheets are loaded in tension, crack extension should commence at tensile loads well below the maximum load for the test. The initial crack extensions are slow because plastic strain zones associated with crack toughness increase in size with crack length. The increase of zone size, representing an increased resistance to crack growth, at first counteracts the intensification of the local stress field due to increased load and crack length. However, the size of the plastic zone must be limited because the crack toughness of the material is limited. Thus, the rate of increase of local stress intensity with crack length presently becomes sufficient for crack extension to continue without increase of the force from the testing machine. This point of maximum load marks the onset of instability and the beginning of rapid crack propagation.

In line with this viewpoint, the testing method proposes measurement of the maximum load and of the crack length at instability. Alternatively, the crack extension prior to instability may be estimated by a semiempirical procedure, based in part upon the percentage of shear lip on the running-crack fracture surface. With the aid of an appropriate stress analysis, the two items of information—the observed maximum load and the observed or estimated crack length at instability—permit calculation of the characteristic stress-field parameter K_c necessary for rapid crack propagation.

Significance of the K parameter as a measure of fracture toughness derives from linear elastic theory. In general, with given conditions of crack length, component configuration, and loads, K can be calculated by stress-analysis procedures. A case of general applicability is the analysis of the region close to a crack on the line of expected crack extension where, neglecting plastic strains, the local normal tensile stress σ_y is given by:

$$\sigma_y = \frac{K}{\sqrt{2\pi r}}$$

where r is the distance from the end of the crack in the x-direction (Fig. 8). Another important case is that of a large sheet containing a small through-the-thickness crack of length $2a$ with an average uniform tensile stress σ acting normal to the crack; the value of K is $\sigma\sqrt{\pi a}$. When the total crack length in such a situation is $2/\pi$ in., σ and K are numerically equal. For this reason, K_c might be described as the "$2/\pi$ in." crack strength of a sheet material. As will be noted from the above relations of K to σ and crack length, the dimensions of K are psi $\times \sqrt{\text{in.}}$

As a mechanical strength property, the K_c-value may be interpreted in the following ways:

(*a*) Relative to the locally elevated stress field at the leading edge of a crack, K_c represents the intensity of local tensile stress necessary for unstable crack propagation.

(*b*) For a crack of length $2a$ in a large sheet, the K_c-value permits estimation of the membrane tensile stress σ necessary for unstable crack propagation through the relationship:

$$\sigma = \frac{K_c}{\sqrt{\pi a}}$$

(*c*) Relative to the modified Griffith theory viewpoint (2,3), the strain energy-release rate $\mathcal{G}_c$ for unstable crack propagation may be directly expressed in terms of K_c by the relationship:

$$K_c^2 = E\mathcal{G}_c$$

where E is Young's modulus. The stress-field parameter interpretation (*a*) is of value in correlating different fracture tests and for understanding the relationship of fracture mode transition

[3] The boldface numbers in parentheses refer to the list of references appended to this report.

TABLE I.—REPRESENTATIVE SPECIMEN DIMENSIONS.

Test-Section Width, in.	Thickness Range, in.		Minimum Length, in.	Loading-Pin Diameter, in.
	Min	Max		
1	0.022	0.063	4	3/8
2	0.044	0.125	8	3/4
3	0.067	0.188	12	1 1/8
4	0.088	0.250	16	1 1/2

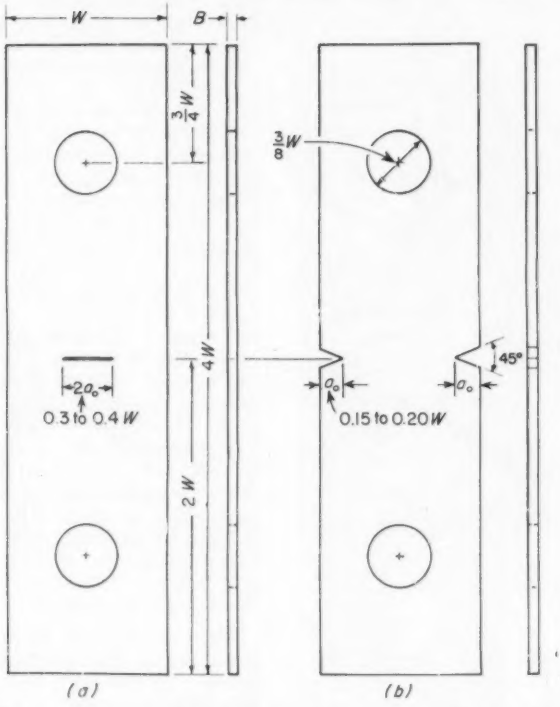


Fig. 1.—Recommended dimensions (*a*) for centrally notched specimen and (*b*) for side-notched specimen.

Width W to thickness B ratio is $16\,B < W < 45\,B$. Pin-hole diamter is $W/3$ to $W/2$. Notch root radius is to be less than 0.001 in. Notch root position is to be symmetrical about line connecting centers of loading pin holes within 0.001 W (inches).

to section thickness, yield stress, and elastic constraint. The crack-strength interpretation (*b*) provides a direct approach to estimating the strength of a component containing a crack of given size. A close relationship of K_c exists not only to the Griffith crack-theory, interpretation (*c*), but also to the Neuber plastic-particle hypothesis (**4**).

Although the general validity of fracture analysis in terms of stress field description is well founded, there are naturally limitations to the range of validity and accuracy of parameters measured by a given test. For the tests here proposed, the stress-analysis considerations are necessarily oversimplified, particularly in the allowances for influence of plastic strains and for slow crack extension. However, the degree of oversimplification is believed to be consistent with other uncertainties inherent in fracture-strength evaluation testing. It is expected that further research will lead to improvements in the basic stress analysis through refinement of its simplifying assumptions. The proposed specimen sizes are selected to include the major portion of the range for which the K_c determination corresponds with useful accuracy to the interpretations given above. This accuracy can be improved by the use of large rather than minimum-size specimens, as will be discussed later.

In certain materials, notably low-carbon structural steels and soft titanium, a pronounced increase of yield strength occurs in a change from static to dynamic load application, an effect leading to a loss of fracture toughness. In high-strength aluminum, titanium, and steel alloys, however, this effect is relatively small. Since it is primarily the latter class of materials that are to be evaluated here, it is expected that the convenience of pulling the specimens in standard slow-speed machines (loading time in the order of minutes) can be utilized.

In tests of thin-walled pressure vessels constructed of high-strength steels, delayed fractures under constant load have occurred in some instances, although in other cases a loss in load-bearing capacity has resulted from a few repeated loadings. The factors that influence gradual initiation and growth of cracks in service structures are complex. Their investigation is and has been the object of numerous research programs. Although some degree of correlation should exist between slow crack-propagation fracture-toughness and tendencies toward low-stress-level crack initiation and growth, the primary emphasis in these tests is on the crack-propagation fracture-toughness only.

Test Specimens and Procedure

Specimen Dimensions

Specimen-design recommendations, summarized in Fig. 1(*a*) for centrally notched and in Fig. 1(*b*) for side-notched specimens, are thought to represent a reasonable compromise between ideal conditions for fracture-toughness evaluation and practicality. To permit economy of material, specimen preparation, and testing time, the test specifications allow specimens that are shorter and narrower than would be best from the viewpoint of stress-analysis precision. Nevertheless, it can be demonstrated that the K_c-values should not be appreciably affected by proximity of the pin grips spaced, as shown, $2\frac{1}{2}$ specimen widths W apart. The effective extension of the actual crack length by the zone of plastic flow has a much larger effect on apparent crack-toughness values, tending to reduce K_c for specimens having low ratios of width W to thickness B. A correction for this plastic-zone size is possible, however, yielding K_c-values close to those which would be obtained for a wide sheet of the same material and, thus, to those which are applicable to interpretation of a small crack in a large thin-sheet structure.

Once the thickness range of the material to be tested is established, considerable choice remains as to lateral dimension of the specimen ($16\,B < W < 45\,B$). Usually, W is chosen to suit an existing set of loading pins, or, if grips must be procured, their size may be chosen for a value of W that is appropriate for the expected range of thicknesses. Table I lists thickness ranges suitable for certain selected values of plate width and pin size.

When the $W:B$ ratio exceeds 45, the behavior of the specimen under load should be watched for evidence of lateral warping or buckling. Such behavior reduces the accuracy of the stress analysis and permits a shearing action at the notch root to reduce the

apparent fracture toughness. Specimen widths greater than 45 B and thus smaller thicknesses than those listed as minimum values in Table I may, nevertheless, provide useful results for special applications. The thickness range in which results can be considered free from buckling influence can be extended by use of lubricated face plate restraints to hold the specimen flat. In general, some means of strengthening and stiffening the specimen ends are found desirable. A suitable pair of clamping plates is shown in Fig. 2; they are bolted together at the sides of the specimen and contain a central hole fitting the loading pin.

Specimen Material

The proposed specimen and test procedure are specifically designed for high-strength sheet materials of yield strength-to-density ratios greater than 700,000 (psi:lb per cu. in.). As noted earlier, this lower limit may include, in addition to the high-strength steels, certain aluminum and titanium alloys. The specimens proposed are also suitable for crack-toughness measurements of the central and border regions of welds. The weld should be located across the center of the specimen and the notch roots placed in the regions which are of interest. Since only the stress field associated with the applied loads can be estimated from the analysis, stress patterns residual to heat treatment or other causes will reduce accuracy of K_c-value measurements and care should be taken to avoid this condition in the material.

Notch Sharpness and Preparation

The desirability of extremely sharp notches may be concluded from observations of many hydrotest-fractures of full- and small-scale solid-propellant chambers. In each full size chamber it was observed that a starting crack was either pre-existent or had formed and extended prior to rapid propagation. As expected from fracture mechanics, larger cracks could usually be associated with lower tensile membrane-stress at failure. Since the low-stress fractures can be associated with flaws in the form of actual cracks, it is considered advisable to measure crack toughness in a specimen relative to an actual crack or a very sharp notch.

Tests with notches of increasing sharpness have indicated, on rather general grounds, the desirability of a root radius of 0.001 in. or less. Blunter than this, excessively high average stress may be required to start a natural crack which, because of the magnitude of the surrounding stress field, may become unstable at an unobservably small size. In many cases, such a crack may form at a point some distance from the notch root, then propagate simultaneously to the notch root and across the specimen. Accordingly, for the K-value test proposed here, a maximum notch-root radius of 0.001 in. or a natural crack of equivalent sharpness is specified. In the event that methods

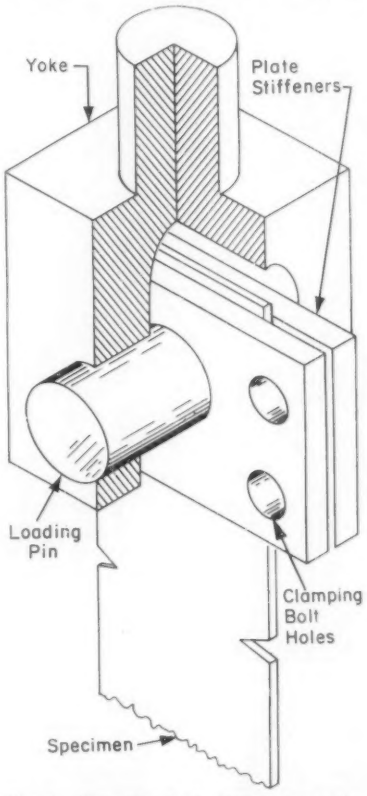


Fig. 2.—Clamping plate arrangement suitable for stiffening thin sheet specimens.

such as fatigue stressing are used to produce short natural cracks extending from notches of larger root radius, it is assumed that the equivalent root radius of the fatigue crack is less than 0.001 in. and, thus, meets the specification. In the event that a staining procedure is used to measure slow crack extension, it is assumed that the 0.001-in. root-radius condition is also met if a slow crack forms and extends prior to maximum load.

Care should be exercised in notch preparation. Shaping the finish cut of a notch with a carefully prepared tool has been successful on side notches and is a promising technique for central notches (see chapter on Screening Tests, methods used in evaluating materials and methods of heat treatment).* Very hard specimens have been notched with electrical discharge machining. Naturally starting crack sat the notch root can be formed by fatigue stressing or by localized hydrogen embrittlement and straining (**6**,**7**,**8**). Localized chilling and wedging has been used to start a natural crack in thick, soft steel specimens (**9**) and may yet prove a useful technique for the specimens proposed.

Notch Depth

The initial notch depth a_0 should lie in the range $0.3 < 2a_0{:}W < 0.4$. This leaves between 60 and 70 per cent of the specimen section for crack growth and propagation. Studies of the stress equations show that, for a constant K-value, the average stress σ_N on the net section $(W - 2a)$ is nearly constant when $2a{:}W$ is in the range from 0.3 to 0.5 and, neglecting the plastic-strain zone, is minimum at 0.4. Thus, allowing for some slow crack growth, crack propagation is expected under nearly minimum conditions of net-section stress when $2a_0{:}W$ is 0.3. The combination of a 45-deg notch-flank angle for edge-notched specimens with the expectation of some slow crack growth due to notch acuity is thought to adequately simulate a simple crack for purpose of stress analysis. Notches should be closely symmetrical about a line connecting pin centers to provide the best possible symmetry of stress distribution at onset of crack growth. A tolerance of 0.001 W (Fig. 1) has been suggested.

Width-to-Thickness Ratio

The accuracy of K as a descriptive parameter of the crack-stress field is of course no better than the accuracy of the stress analysis on which K is based. Although an approximate correction is used to offset neglect of plastic strains in the stress analysis, the probable error of the analysis becomes seriously large as the net-section stress σ_N increases beyond the tensile yield strength σ_{YS}. The stress-analysis inaccuracy of K when $\sigma_N = \sigma_{YS}$ is believed to be less than 10 per cent, and computations of K are believed to retain useful comparative validity until $\sigma_N = 1.10\ \sigma_{YS}$. For $\sigma_N > 1.10\ \sigma_{YS}$, the computed K is at least known to be less than that obtained with a specimen large enough for an accurate determination. Computations show that the condition $\sigma_N \leq \sigma_{YS}$ corresponds approximately to $K_c \leq K_m$, where $K_m^2 = 0.38\ W\ \sigma_{YS}^2$.

The linear extent of the plastic zone, as discussed under Stress Analysis of Selected Tensile Specimens, is proportional to K^2/σ_{YS}^2. Because of the relationship of relative plastic zone size to fracture mode transition, it is helpful to define a quantity β, the measure of the relative plastic zone size, by the equation:

$$\beta = \frac{K_c^2}{B\sigma_{YS}^2} \qquad (1)$$

* This chapter comprises part of the second and concluding installment of this report, which will be published in the ASTM BULLETIN issue of February, 1960.

In terms of β-value, a measured K_c is less than K_m when:

$$\beta < 0.38 \frac{W}{B} \quad \ldots\ldots\ldots\ldots (2)$$

In general, the appearance of the fracture propagation surface in terms of percentage of shear lip P can be correlated with β as shown in Fig. 3. The appearance parameter P is quite sensitive to β up to zone sizes of $\beta = 2\pi$, a value covering the major portion of the fracture-mode transition range.

The investigations employing the proposed test are concerned with materials of widely varying brittleness. The degree of brittleness corresponding to $\beta = 2\pi$ has a double significance. As will be shown later under Practical Applications of K_c-Values, the toughness corresponding to $\beta = 2\pi$ is approximately the value needed to arrest propagation of a small through-the-thickness crack when σ is as large as σ_{YS}. In addition, this β-value is not far from the upper end of the zone of fracture-mode transition from transverse tension to oblique shear. In order that the K_c measurements have an accuracy corresponding to $\sigma_N < \sigma_{YS}$ through the major portion of the critical fracture-mode transition zone it is desirable to have W/B large enough to satisfy the inequality (Eq 2) above with $\beta = 2\pi$. A width W of 16 B is the minimum size that meets this requirement.

Staining Techniques for Slow Crack Measurement

Use of a liquid-dye staining technique for indicating the extent of slow crack growth or value of a is simple, inexpensive, and has been employed for numerous routine evaluation tests. Several staining fluids have been utilized successfully:

1. Black or red India ink,
2. Chart-recorder ink, and
3. A mixture of 65 per cent glycerine and 35 per cent water to which is added a small amount of an aniline dye.

The water dispersions are useful only between 0 and 100 C, whereas additions of glycerine allow the testing temperature to be lowered to −75 C, the sublimation temperature of carbon dioxide.

First, the machined notch should be cleaned of oily deposits to allow optimum wetting of the metal surface. A small quantity of the selected marking fluid is then dropped into the notch root just prior to loading. As the crack extends, this liquid is sucked into the vacuum produced at the tip of the crack. As the crack opens at the plate surface, surface tension holds the liquid in the crevice. Additional fluid may be added as necessary to maintain a sufficient supply as the crack grows, or a larger initial volume may be provided by flanking the notch with walls of a pressure-sensitive transparent tape.

With the inks, care must be exercised to complete the test before the supply congeals in the crack. Since the glycerine base is slow-drying, it must be blotted immediately after fracture.

When the crack runs rapidly, the stain cannot follow. This termination of stain then indicates the extent of slow crack growth. The leading edge of the crack is usually curved, and the stain termination point, which can be estimated by eye, is taken on a line, perpendicular to the specimen surface, that equally divides the stained area ahead from the unstained area behind. For a center-crack specimen, $2a$ is the distance between the stain-indicated terminal points. For an edge-notched specimen, $2a$ is W minus this distance.

Prompt examination of the ink stain should follow the fracture event. The upper half of the surface, being less likely to contain spatter, is preferable for examination, particularly when it indicates a smaller value for $2a$.

Test Procedure

Fracture of these specimens is obtained by axial loading in a conventional tension testing machine that permits measurement of the maximum load σ_M. The speed of testing should be such that the loads used in obtaining test results are accurately indicated. Careful mounting is important to obtain axiality of load application. In addition to the load, a measure of slow crack growth may be obtained as described under Staining Techniques for Slow Crack Measurement or the measurement of shear-lip fraction P may be employed to assist an indirect estimate of a. The shear-lip fraction is defined as (B − flat fracture-width)/B in the crack path between B and 2 B from the side edge of a centrally notched specimen or $B/2$ on either side of the center of an edge-notched specimen. Specimen dimensions, including a_0, W, and B, as well as testing temperature should be recorded. A value of the tensile yield strength σ_{YS}, measured on unnotched specimens of the same stock as the fracture test specimen, is recommended. Standard methods of measuring a 0.2 per cent offset tensile yield strength are recommended with the specimen ends designed for the pins and specimen end stiffeners employed in fracture testing. In the absence of this, the best estimate of σ_{YS} from existing information may be recorded for use in the calculation of K_c. The error in K_c from a 10 per cent error in the assumed σ_{YS} is generally less than 2 per cent.

Computation of K-Values

The fracture mechanics basic to the K-value viewpoint is that any two systems for applying tension to a developing crack are equivalent if they create the same elastic-stress environment around the advancing edge of the crack. It is the object of the analysis to characterize this stress environment by determining the stress-field parameter K (see Stress Analysis of Selected Tension Specimens) at the point of instability where it is equal to K_c, a material property. Values of K at instability are computed from the general equation:

$$K_c = \sigma_M \sqrt{q_c W} \quad \ldots\ldots\ldots (3)$$

where σ_M is the maximum gross-section stress, and q_c, a number of the order of unity, is a function of specimen geometry, crack length, and load at instability. The procedure outlined here and justified under Stress Analysis of Selected Tension Specimens permits calculation of the value of K_c for each of the two specimen shapes and two

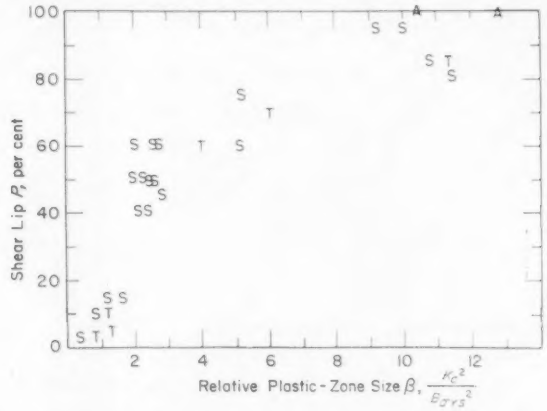


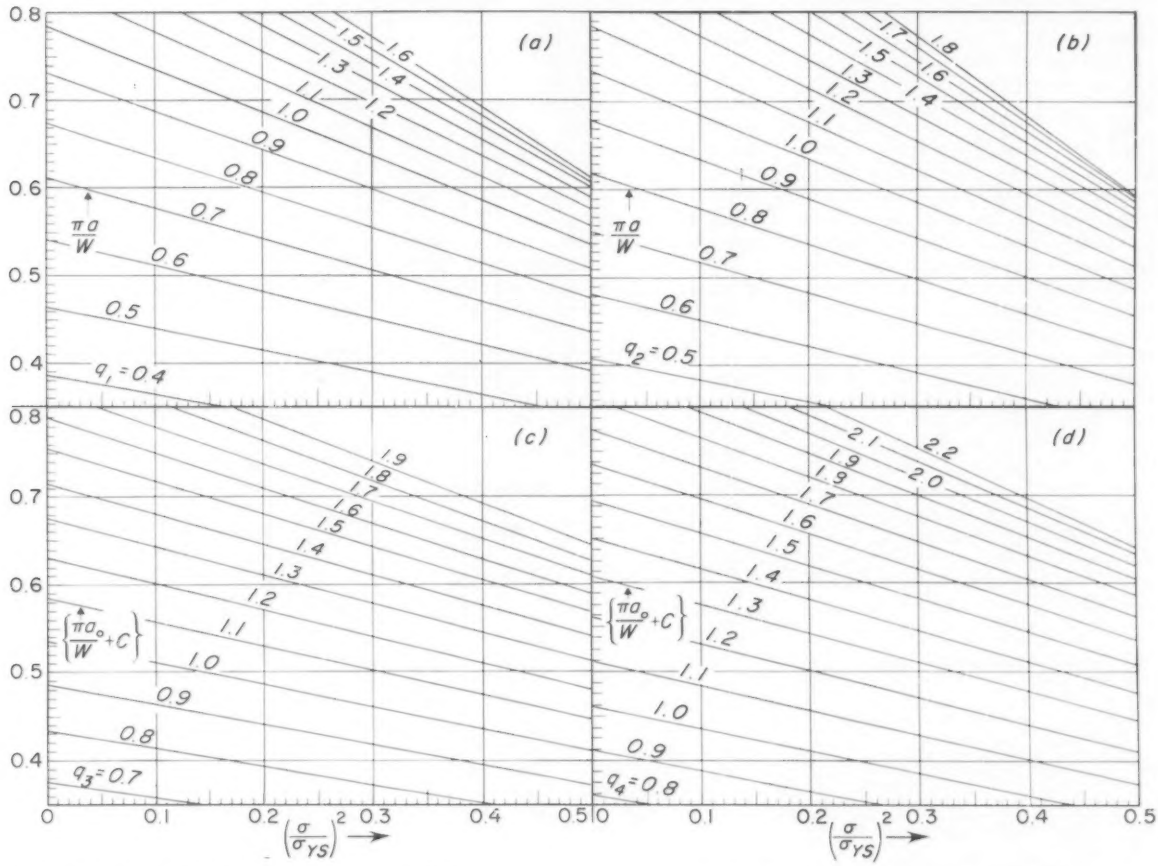
Fig. 3.—Percentage of shear lip of the propagating crack for high-strength alloys of steel (S), aluminum (A), and titanium (T) as a function of relative plastic-zone size β.

means of determining slow crack length. The results of any of the four methods of crack-toughness evaluation should give the same value of K_c for a given material (in the absence of differing residual stress patterns). For convenience, the values will be distinguished here by an added subscript, corresponding to the kind of test, as follows:

with a graphical method. The computation scheme is outlined in Table II for each of the four methods with reference to Fig. 4, from which one may read off q_c-values.

Examples of typical results for variously heat-treated AISI 4340 steel are given in Table III for the measured crack-length method and in Table IV

For the aluminum alloy shown, the effect becomes appreciable at thickness levels above $\frac{1}{8}$ in., that is, halfway through the thickness range discussed in this paper. Plane-strain toughness values at the extreme left are necessary for interpretation of growth of an embedded crack as discussed later. In support of equivalency of side-notched



(*a*) For K_{c1}-calculation (central notch, measured crack *a*).

(*b*) For K_{c2}-calculation (edge notch, measured crack *a*).

(*c*) For K_{c3}-calculation (central notch, without ink stain).

(*d*) For K_{c4}-calculation (edge notch, without ink stain)

Fig. 4.—Graphical representation of q_c-values.

K_{c1} and K_{c2}, by direct measurement of the critical crack length a with specimens respectively centrally notched (Eqs 24, 25, and 23) and edge-notched (Eqs 21, 22, and 23).

K_{c3} and K_{c4}, by indirect estimate of critical crack length from a_0 and a percentage of shear, P, measurement with specimens respectively centrally notched and edge-notched (see Notch Depth and reference (1)).

Correction of these narrow-specimen results for the plastic-zone size (which varies with K_c), while necessary to allow comparison with fracture in wide sheets in actual structures, introduces the complexity of having the expression for K_c implicit in K_c. However, the calculation is readily carried out

for the same data analyzed by estimating the slow crack growth. The calculation procedure described above was employed. Table V lists average values of K_{c1} and K_{c3} for selected materials.

It will be noted in Table V that the K_c-values for sheet thickness of 0.22 in. are generally lower than those for the same material in 0.07-in. thickness. This decrease in crack toughness is associated with increased elastic constraint—or approach to the plane strain condition—with increased section thickness. Although fracture of thick sections is not discussed here, the trend to be expected is illustrated by Fig. 5 which shows K_c-values for a wide range of specimen thickness.

and center-notched specimens, it will be noted that tests with both types at $\frac{3}{16}$-in. thickness give essentially identical toughness values.

Practical Applications of K_c-Values

Calculation of a Serious Flaw Length from Plane-Stress K_c-Values

Fracture of a plate or shell structure in service often occurs from an embedded crack that first extends through the section thickness under plane-strain conditions. The extension of embedded cracks can be discussed in terms of a plane-strain K_c-value such as illustrated in Fig. 5. After a through-thickness crack has been established, the sheet-specimen K_c-value, obtained by the procedures discussed here, be-

comes the critical factor governing the arrest or propagation of the crack.[4]

There are two lines of defense against crack propagation. While the crack is spreading as an embedded crack, the governing crack toughness corresponds to plane-strain conditions and is relatively low (10). If the stresses are high, very small cracks must be regarded as dangerous. For example,[5] at a stress of 200,000 psi, a surface crack 0.016 in. deep is likely to propagate unless K_c is more than 55,000 psi $\sqrt{\text{in.}}$ A plane-strain crack-toughness of this magnitude is not exceptionally low for high-strength steels, particularly in regions around welds. The first line of defense consists in reduction of stresses by better design and improved inspection to eliminate small cracks and notches, as well as optimum obtainable fracture toughness.

If the crack succeeds nevertheless in penetrating the thickness, there exists a second line of defense, the possibility that crack-extension across the sheet may be arrested by the growth of fracture toughness associated with the decrease in degree of plane strain. The required toughness is given by:

$$K_c^2 = \pi\sigma^2 a_1 \quad \ldots\ldots\ldots (4)$$

where a_1 is the "effective" half-length of the crack or a corrected for local plastic strains as discussed under Stress Analysis of Selected Tension Specimens. In terms of the actual half-length a, this requirement becomes:

$$K_c^2 = \frac{\pi\sigma^2 a}{1 - \frac{1}{2}\left(\frac{\sigma}{\sigma_{YS}}\right)^2} \quad \ldots\ldots (5)$$

As a specific illustration, consider Fig. 6. The original flaw, shown shaded, extends slowly from position (1) to position (2), then extends rapidly with an audible click to position (3), where it is arrested. Figure 6 was drawn assuming a plate of 0.075-in. thickness, having a crack toughness K_c of 140,000 psi $\sqrt{\text{in.}}$ and the average membrane-stress and tensile yield stress equal to 200,000 psi. The locus for onset of rapid propagation as a plane-strain fracture, position (2), was estimated assuming a plane strain K_c-value of 57,000 psi $\sqrt{\text{in.}}$ or, equivalently, 66,000 psi $\sqrt{\text{in.}}$ with a 15 per cent stress elevation due to superimposed bending. In this case, the depth of position (2) is nearly 0.018 in. and the depth of position (1) roughly half as great, say 0.01 in. Since a flaw at the surface extends along a roughly circular front, a crack length of about two thicknesses (2 B) might be considered a minimum size ($a = B$). Smaller cracks tend to grow to this size. When $\sigma = \sigma_{YS}$ and $a = B$, Eq 5 corresponds to the condition $\beta = 2\pi$.

[4] A possible added influence of biaxiality is neglected here (see the biaxial stress-field parameter, σ_{sz}, under Stress Analysis of Selected Tensile Specimens.

[5] Eq 17, with a increased by 0.004 in. as an assumed plastic-zone correction.

TABLE II.—SCHEME FOR K_c CALCULATION.

a = Slow crack length.
W = Specimen width.
σ = Gross section stress at onset of fast fracture.
σ_{YS} = Yield strength.
P = Per cent shear.
a_0 = Notch depth from center line or edge.
B = Specimen width.

COMPUTATION WITH MEASURED CRACK LENGTH a

Specimen Type.....	Center Notch	Edge Notch
Measurements.....	a, W, B, σ, σ_{YS}	a, W, B, σ, σ_{YS}
Compute.....	1. $y = \frac{\pi a}{W}$	$y = \frac{\pi a}{W}$
	2. $x = \left(\frac{\sigma}{\sigma_{YS}}\right)^2$	$x = \left(\frac{\sigma}{\sigma_{YS}}\right)^2$
Plot point (x,y) on.....	3. Fig. 4(a)	Fig. 4(b)
Read.....	4. q_1 (visual interpolation)	q_2 (visual interpolation)
Compute.....	5. $K_{c1} = \sigma\sqrt{q_1 W}$	$K_{c2} = \sigma\sqrt{q_2 W}$

COMPUTATION WITH CRACK LENGTH ESTIMATED FROM P AND a_0

Specimen Type.....	Center Notch, K_{c3}	Edge Notch, K_{c4}
Measurements.....	a_0, W, B, σ, σ_{YS}, P	a_0, W, B, σ, σ_{YS}, P
Compute.....	1. $\frac{\pi a_0}{W}$	$\frac{\pi a_0}{W}$
	2. $c = 4.7\ (P - 0.43)\frac{B}{W}$	$c = 4.7\ (P - 0.43)\ \frac{B}{W}$
	3. $y = \frac{\pi a_0}{W} + c$	$y = \frac{\pi a_0}{W} + c$
	4. $x = \left(\frac{\sigma}{\sigma_{YS}}\right)^2$	$x = \left(\frac{\sigma}{\sigma_{YS}}\right)^2$
Plot point (x, y) on.....	5. Fig. 4(c)	Fig. 4(d)
Read.....	6. q_3 (visual interpolation)	q_4 (visual interpolation)
Compute.....	7. $K_{c3} = \sigma\sqrt{q_3 W}$	$K_{c4} = \sigma\sqrt{q_4 W}$

TABLE III.—TYPICAL DATA[a] FOR CALCULATION OF $K_{c1} = \sigma\sqrt{q_1 W}$.

NOTE.—Material: AISI 4340, air melt; specimen: longitudinal, B = 0.080 in., W = 3.00 in., W/B = 37.5, center notch.

Tempering Temperature, deg Fahr	σ_{YS}, 1000 psi	σ, 1000 psi	a, in.	$\frac{\pi a}{W}$	$\left(\frac{\sigma}{\sigma_{YS}}\right)^2$	q_1[a]	$q_1 W$, in.	$\sqrt{q_1 W}$, $\sqrt{\text{in.}}$	K_{c1}, 1000 psi $\sqrt{\text{in.}}$	Avg K_{c1}, 1000 psi $\sqrt{\text{in.}}$
350.....	208.3	93.6	0.71	0.744	0.202	1.18	3.54	1.88	176	...
	...	97.7	0.72	0.754	0.220	1.20	3.60	1.90	185	...
	...	113.9	0.67	0.702	0.299	1.21	3.63	1.96	223	...
	...	96.9	0.71	0.744	0.216	1.20	3.60	1.90	184	192
425.....	203.9	108.1	0.70	0.733	0.281	1.32	3.96	1.99	215	...
	...	107.1	0.73	0.764	0.276	1.45	4.35	2.09	224	...
	...	114.4	0.67	0.701	0.315	1.26	3.78	1.94	203	...
	...	103.9	0.59	0.618	0.259	0.92	2.76	1.66	173	204
500.....	197.9	98.4	0.56	0.586	0.247	0.83	2.49	1.58	156	...
	...	96.4	0.70	0.733	0.236	1.20	3.60	1.90	189	...
	...	106.0	0.59	0.618	0.286	0.93	2.79	1.67	177	...
	...	95.0	0.68	0.712	0.230	1.11	3.33	1.83	174	174
700.....	181.6	107.5	0.62	0.649	0.351	1.13	3.39	1.84	198	...
	...	120.6	0.62	0.649	0.441	1.50	4.50	2.12	255	...
	...	58.2[b]	0.70	0.733	0.102	1.00	3.00	1.73	101	...
	...	120.6	0.63	0.660	0.441	1.60	4.80	2.19	264	204.5

[a] Data supplied by Richard Rawe, Aerojet General Co., Azusa, Calif.

[a] See Fig. 4(a), read on interpolated line through point $\left(\frac{\sigma}{\sigma_{YS}}\right)^2$, $\frac{\pi a}{W}$.

[b] Data unexplained.

Post-Fracture Examinations

Examination of a fracture in service must begin with a determination of the location and size of the primary fracture origin from which the run of the crack occurred. In pressure-vessel fractures from internal pressure, the ability of the material to arrest a through-thickness crack (length 2 B or more) is indicated by a local outward bulge of the plate adjacent to the starting crack. Thus the value of K_c, calculated from Eq 5, establishes a lower limit for the actual K_c-value. On the other hand, if there is no indication of crack arrest, then K_c so calculated represents an

TABLE IV.—TYPICAL DATA FOR CALCULATION OF $K_{c1} = \sigma\sqrt{q_2 W}$.

NOTE.—Material: AISI 4340, air melt; specimen: longitudinal, B = 0.080 in., W = 3.00 in., $W:B$ = 37.5, center notch.

Tempering Temperature, deg Fahr	σ_{YS}, 1000 psi	σ, 1000 psi	a_0, in.	P	$\frac{\pi a_1}{W}$	c	$\frac{\pi a_0}{W} + c$	$\left(\frac{\sigma}{\sigma_{YS}}\right)^2$	q_2*	$q_2 W$, in.	$\sqrt{q_2 W}$, $\sqrt{\text{in.}}$	K_{c1}, 1000 psi $\sqrt{\text{in.}}$	Avg K_{c1}, 1000 psi $\sqrt{\text{in.}}$	Avg K_{c1}, 1000 psi $\sqrt{\text{in.}}$
350.....	208.3	93.6	0.39	0.62	0.412	0.024	0.436	0.202	0.89	2.67	1.63	153	...	...
	...	97.7	...	0.87	...	0.055	0.468	0.220	0.99	2.97	1.73	169	...	...
	...	113.9	...	0.87	...	0.055	0.468	0.299	1.03	3.10	1.76	174	...	...
	...	96.9	...	0.75	...	0.040	0.452	0.216	0.94	2.82	1.68	163	165	192
425.....	203.9	108.1	0.39	0.95	0.412	0.065	0.478	0.281	1.04	3.12	1.77	191	...	...
	...	107.1	...	0.80	...	0.046	0.459	0.276	0.98	2.94	1.72	184	...	...
	...	114.4	...	1.00	...	0.071	0.484	0.315	1.08	3.24	1.80	189	...	...
	...	103.9	...	0.95	...	0.065	0.478	0.259	1.02	3.06	1.75	182	187	204
500.....	197.9	98.4	0.39	0.70	0.412	0.034	0.446	0.247	0.93	2.80	1.67	164	...	...
	...	96.1	...	1.00	...	0.071	0.484	0.236	1.02	3.06	1.75	168	...	...
	...	106.0	...	0.60	...	0.024	0.436	0.286	0.94	2.82	1.68	179	...	...
	...	95	...	0.80	...	0.046	0.453	0.230	0.94	2.82	1.68	160	168	174
700.....	181.6	107.5	0.39	1.00	0.412	0.071	0.484	0.351	1.10	3.30	1.82	195	...	...
	...	120.6	...	1.00	...	0.071	0.484	0.441	1.15	3.45	1.86	225	...	...
	...	58.2	...	0.50	...	0.009	0.421	0.102	0.82	2.46	1.57	91.2	...	...
	...	120.6	...	1.00	...	0.071	0.484	0.440	1.15	3.45	1.86	225	186.5	204.5

* See Fig. 4(c), read on interpolated line through point $\left(\frac{\sigma}{\sigma_{YS}}\right)^2, \left(\frac{\pi a_0}{W} + c\right)$.

upper limit of possible values.

It is helpful to check the consistence of such references with all known facts. To estimate the minimum or maximum K_c, values of a, σ, and σ_{YS} are needed. Reasonable estimates of σ and σ_{YS} are presumably available. Unless the fracture markings indicate a larger value, the half-length of the crack, a, can be given a nominal value equal to the plate thickness. The result of the calculation can be compared with the crack toughness expected from prior tests of the material. Alternatively, if there is reason to believe the K_c-value for the material has a definite known value, this value can be used with Eq 5 to determine a value of the half-length of the crack, a. Again, it may be the stress that is considered most uncertain, in which case σ can be computed and consideration given to whether the computed value was possible under the prevailing circumstances.

Optimum Design Viewpoint Based on Balance of Toughness and Yield Strength

In the heat treatment of a high-strength steel alloy, it is often possible to obtain a greater degree of fracture toughness at the expense of some loss of yield strength. Selection of an optimum balance between toughness and yield stress corresponds by implication to estimating the size of the largest crack or flaw that may persist in spite of fabrication care and inspection. For any specific flaw size there is a fracture-toughness value that corresponds to the maximum usable strength. This optimum strength condition may be described as one in which failure by general yielding and failure by crack propagation are equally probable with neither mechanism of failure dominant.[6]

This is illustrated in Fig. 7, which shows the loci of the failure stresses as a function of crack length for a given material in each of two heat-treated conditions. In either case, failure occurs by excessive permanent strain when a certain flow stress is reached, provided that the crack length is less than a certain size (different for the two different conditions). This is represented by the horizontal portion of each locus, labeled Y or Y'. Beyond this crack size, failure is by fracture at a stress corresponding to the curved part of the locus line, labeled F or F', which represents a fixed value of K_c. If the crack length is l, corresponding to the intersection of the flow part and the fracture part of the locus for the softer but tougher condition, then, from Fig. 7, the failure stress for this condition is higher than for the harder but less tough condition. Any further decrease in flow stress only serves to reduce the failure stress. As noted above, it is dangerous to assume that l will ever be less than 2 B in practical structures.

[6] Suggested by J. A. Kies.

TABLE V.—TYPICAL DATA FOR VARIOUS MATERIALS (AVERAGE).

Specimens	B, in.	σ_{YS}, 1000 psi	σ, 1000 psi	a, in.	K_{c1}, 1000 psi $\sqrt{\text{in.}}$	K_{c2}, 1000 psi $\sqrt{\text{in.}}$
Material 6434[a]						
Air melt						
Longitudinal.....	0.07	190	102	0.67	194	205
	0.22	190	107	0.76	269	251
	0.07	210	107	0.66	198	218
	0.22	210	88.5	0.82	191	185
Vacuum melt						
Longitudinal.....	0.07	190	100	0.72	205	200
	0.22	190	88	0.77	183	184
	0.07	210	97.4	0.69	180	191
	0.22	210	83.5	0.78	166.4	165
Transverse.....	0.07	190	95.7	0.73	195.5	191
	0.22	190	83.6	0.83	185.5	181
	0.07	210	100.4	0.83	201.5	197
	0.22	210	74.6	0.78	144	140
Material Tricent[a]						
Vacuum melt						
Longitudinal.....	0.07	190	93	0.76	197	183
	0.22	190	69.4	0.61	109.8	108.5
	0.07	230	109	0.75	219	214
	0.22	230	77.9	0.74	144	132
Transverse.....	0.07	190	95	0.77	204.5	187
	0.22	190	70	0.56	104	108.8
	0.07	230	108.5	0.76	227.5	214
	0.22	230	77.4	0.78	159.5	452
Material Ti-6Al,4[b]						
Longitudinal.....	0.072	159	68.7	0.63	114	123
Transverse.....	0.072	164	72.8	0.68	113	132

[a] Data supplied by G. C. Young, Navy Weapons Plant, Washington, D.C.
[b] Data supplied by R. Rawe, Aerojet General Co., Azusa, Calif.

Stress Analysis of Selected Tension Specimens[7]

As indicated earlier, the significance of the K_c-value stems from its relationship to the stresses near the leading edge of a crack. A brief review of the essential stress analysis considerations

[7] In the literature on fracture mechanics, the related parameters $\mathfrak{K} = K/\sqrt{\pi}$ and $\mathcal{G} = K^2/E$, where E is Young's modulus, are usually employed rather than K.

is provided in the following paragraphs. More complete discussions of the topics considered are available (1, 11, 12, 13, 14).

Figures 8(*a*) and (*b*) show two notched flat-sheet tension specimens. Notches, symmetrical about the specimen axes, are shown with crack extensions from the notch roots. The analysis is concerned with these crack extensions and with characterization of the stress field that surrounds them.

It is the stresses close to the leading edge of the crack that are of primary interest. Putting $x = a + r$, and assuming r/a very small, one finds from Eqs 6 and 7 that:

$$\sigma_y = \frac{K}{\sqrt{2\pi r}} \quad \ldots\ldots\ldots(9)$$

$$\sigma_x = \frac{K}{\sqrt{2\pi r}} - \sigma_{0x} \quad \ldots\ldots(10)$$

where:

The designation of local stress-level influence by a single stress field parameter K is based on a two-dimensional stress analysis that can describe either a situation of plane stress or of plane strain. For the tests discussed here, the ratio of lateral specimen dimensions to sheet thickness is large enough so that the crack-edge stress environment is best characterized by the plane-stress analysis.

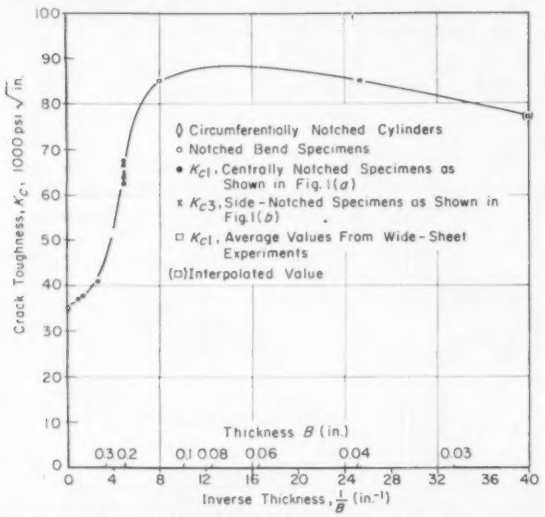


Fig. 5.—Effect of specimen thickness B on crack toughness values K_c for 70.75T6 aluminum.

Plane-strain K_c-values appear at extreme left for very thick specimens.

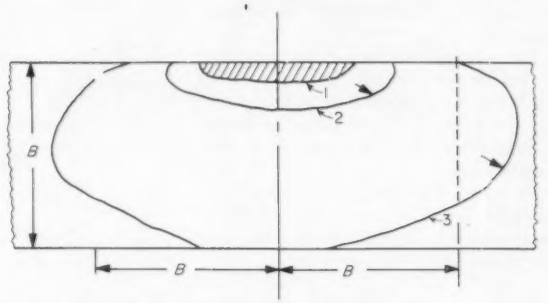


Fig. 6.—Sketch of fracture origin (1), slow growth to (2), fast fracture to (3) with arrest due to toughness associated with plane-stress situation.

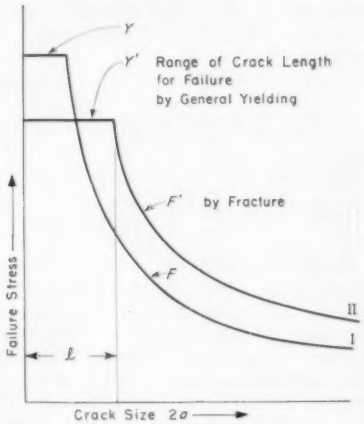


Fig. 7.—Effect of reducing yield strength (region Y) on fracture toughness (region F)

Choice of optimum properties depends on maximum flaw size which may occur. For flaw size l, curve II is optimum.

Analysis of Centrally-Notched Tension Specimen

For the specimen of Fig. 8(*a*), advantage may be taken of the fact that a stress-analysis solution in closed form is known that nearly fits the boundary conditions (11). Taking the vertical and horizontal axes of symmetry of the centrally-notched specimen as the y and x Cartesian coordinate axes, the stresses along the x-axis ($y = 0$) from this approximate stress solution are:

$$\sigma_y = \sigma \left\{ 1 - \left(\frac{\sin \frac{\pi a}{W}}{\sin \frac{\pi x}{W}} \right)^2 \right\}^{-\frac{1}{2}} \quad \ldots\ldots\ldots(6)$$

$$\sigma_x = \sigma \left\{ 1 - \left(\frac{\sin \frac{\pi a}{W}}{\sin \frac{\pi x}{W}} \right)^2 \right\}^{-\frac{1}{2}} - \sigma_{0x} \ldots(7)$$

$$\tau_{xy} = 0 \quad \ldots\ldots\ldots(8)$$

In these equations, a and W are respectively the half-width of the crack and the specimen width, and σ is the gross-section average stress obtained from the tensile load divided by the area WB, where B represents specimen thickness.

$$K = \sigma \left\{ W \tan \frac{\pi a}{W} \right\}^{\frac{1}{2}} \quad \ldots\ldots(11)$$

Equations 9 and 10 give the values which σ_x and σ_y approach as r approaches zero. By use of polar coordinates r, θ as shown in Fig. 8, the crack-edge stress-field equations may be written more completely as:

$$\sigma_y = \frac{K}{\sqrt{2\pi r}} \cos \frac{\theta}{2} \left\{ 1 + \sin \frac{\theta}{2} \sin \frac{3\theta}{2} \right\} \quad \ldots\ldots\ldots(12)$$

$$\sigma_x = \frac{K}{\sqrt{2\pi r}} \cos \frac{\theta}{2} \left\{ 1 - \sin \frac{\theta}{2} \sin \frac{3\theta}{2} \right\} - \sigma_{0x} \quad \ldots\ldots\ldots(13)$$

with K as given by Eq 11.

Equations 9, 10, 12, and 13 depend on specimen geometry, crack length, and applied tensile load only through the two parameters K and σ_{0x}, which characterize the stress level in the zone of locally elevated stress. A further simplification to a one-parameter description is obtained by neglecting the influence on the stress field of the parameter σ_{0x}. Justification for neglecting this term is based on the following facts: (1) close to the crack, the term σ_{0x} is relatively small, (2) it has little effect on the shear stresses that control the plastic-zone size and fracture toughness, and (3) tests in which σ_{0x} was systematically varied showed nil effect on K_c-values.

Correction of Stress Analysis for Plastic-Zone Size

A large plastic zone surrounding the crack tip denotes desirable crack-toughness properties or high K_c-values. But its very presence leads to an underestimate of K_c if no correction is made for it. The plastic zone appears to the stress field as a region of somewhat relieved normal stress σ_y, an effect roughly comparable to an extra extension of the crack. Without adjustment for influence of plastic strains, K_c-values for narrow specimens are much lower than those for wide specimens and, thus, do not reflect crack-toughness values proper for analysis of fracture in wide sheets. Accordingly, it is de-

sirable to correct the stress equations to compensate for this effect. Experimental stress-field investigation of a centrally notched specimen showed increasing departures from Eqs 6 and 7 as the load increased. Close agreement of these equations with experimental results could be obtained by replacing gross-section stress σ and crack length a by somewhat larger values, σ_1 and a_1. The magnitude and direction of these adjustments were consistent with approximate theoretical estimates.

For purposes of estimating the value of the stress-intensity parameter K, the labor of calculation may be greatly reduced without serious loss of accuracy by assigning the entire burden of the plastic-zone correction to a_1. If one puts σ_y in Eq 9 equal to the yield strength σ_{YS} and solves Eq 9 for the corresponding distance from the end of the crack, r_Y, the result is:

$$r_Y = \frac{K^2}{2\pi\sigma_{YS}^2} \quad \ldots\ldots\ldots (14)$$

To a satisfactory first approximation, one can assume the local stress-relaxing influence of the plastic strains to be equivalent to an added crack length equal to r_{YS}.

Thus, a_1 becomes:

$$a_1 = a + \frac{K^2}{2\pi\sigma_{YS}^2} \quad \ldots\ldots\ldots (15)$$

Replacing a by a_1 in Eq 11 gives:

$$K^2 = \sigma^2 W \tan\left(\frac{\pi a}{W} + \frac{K^2}{2W\sigma_{YS}^2}\right) \quad \ldots (16)$$

Applied to data now available, this correction is found to improve significantly the consistency of K_c-values obtained with specimens of different widths. As more data become available, correction procedures of somewhat greater accuracy may well be found.

Analysis of Edge-Notched Tension Specimen

Consider next the stress-analysis problem presented by the edge-notched specimen of Fig. 8(*b*). For deep slots with values of a greater than $W/4$, the stress analysis as employed for the centrally-notched specimen (Eqs 6, 7, 11) nearly fits the boundary conditions if the y-axis is taken at one side boundary of the specimen.

When a is nearly $W/4$, the approximate solution provided by the Westergaard repeated crack-stress function has less inaccuracy in application to the center-crack than to the edge-crack specimen because the normal stresses on the side boundaries, neglected by such a stress analysis, are much smaller for the center-crack case. However, for very small values of a/W, the effect of removing the side-boundary normal stresses is accurately known. This permits appropriate correction of the stress analysis applied to edge-notched test specimens.

For shallow edge slots, it is known that the value of K can be calculated from the relation:

$$K^2 = 1.2\pi\sigma^2 a \quad \ldots\ldots\ldots (17)$$

This is the relation anticipated when a/W is so small that the specimen width itself is unimportant in the stress analysis. For the same limiting case, Eq 11 predicts:

$$K^2 = \pi\sigma^2 a \quad \ldots\ldots\ldots (18)$$

a result 20 per cent too small.

Since a complete stress-field solution is not required, calculation of K from the relation:

$$K^2 = \sigma^2 W \tan\frac{\pi a}{W}\left\{1 + 0.2\left(\cos\frac{\pi a}{W}\right)^2\right\} \quad \ldots\ldots\ldots (19)$$

would appear to provide a good interpolation. When a/W is small, Eq 19 is equivalent to Eq 17. For a/W approaching $\frac{1}{2}$ corresponding to the deep-notch case, $\left(\cos\frac{\pi a}{W}\right)^2$ is essentially zero and Eq 19 then does not differ appreciably from Eq 11. It is expected on general grounds that the shallow-notch limit and deep-notch limit should possess ranges of validity of comparable extent. Equation 19 is justifiable on the grounds that it provides such ranges for the two limiting situations with a minimum degree of mathematical complexity.

Determination of K-values by use of Eq 19 and the specimen geometry of Fig. 8(*b*) provides a stress-analysis accuracy equivalent to that for the centrally notched specimen. For convenience of calculation, Eq 19 may be rewritten as:

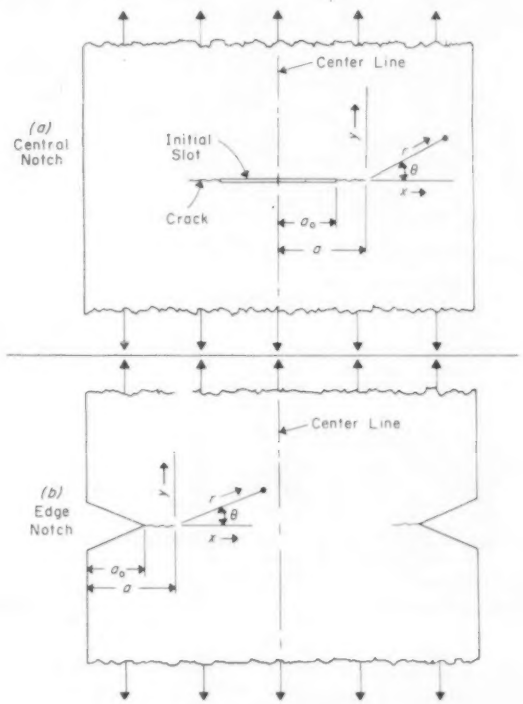


Fig. 8.—Diagram of specimens.

Rectangular and polar coordinate systems for stress analysis have origin at tip of crack.

$$K^2 = \sigma^2 W\left\{\tan\frac{\pi a}{W} + 0.1\sin\frac{2\pi a}{W}\right\} \quad \ldots\ldots\ldots (20)$$

Since the factors related to influence of plastic strain-zone size are quite similar for centrally notched and edge-notched tension specimens, it is assumed that an improved representation of the stress field is obtained if a_1, the crack length corrected for plastic zone size from Eq 15, is employed in Eqs 19 and 20. Thus:

$$K^2 = \sigma^2 W q_2(u) \quad \ldots\ldots\ldots (21)$$

where:

$$q_2(u) = \tan u + 0.1\sin 2u \quad \ldots (22)$$

and

$$u = \frac{\pi a}{W} + \frac{K^2}{2W\sigma_Y^2} \quad \ldots\ldots\ldots (23)$$

The corresponding relations for the centrally notched specimens may be written:

$$K^2 = \sigma^2 W q_1(u) \quad \ldots\ldots\ldots (24)$$

where:

$$q_1(u) = \tan u \quad \ldots\ldots\ldots (25)$$

and u is as given in Eq 23.

Equation 23 rewritten in the form:

$$u(q_2) = \frac{\pi a}{W} + \frac{1}{2}\left(\frac{\sigma}{\sigma_{YS}}\right)^2 q_2$$

provides the basis for a simple graphical method for finding q_2 from the test-measurement data. In a graph of $\pi a/W$ against $(\sigma/\sigma_{YS})^2$, the loci of constant q_2-values are straight lines as shown in Fig. 4(*b*). The analogous relationship with q_1 in place of q_2 provides the basis for Fig. 4(*a*).

Estimate of Slow Crack Extension for K_c-Value Determination

Equations for K_c using slow crack extensions estimated in this way are discussed more completely in reference (1).

The procedure of obtaining K_c-values without use of slow crack staining (K_{c3}, K_{c4}) is based on empirical observations in tests of centrally notched specimens. The procedure should be equally appropriate for edge-notched specimens. Essentially, the estimation procedure is based on a study of the balance between the crack-extension force, $\mathcal{G}$, and the resistance to crack extension, R, where R was given a simple empirical form with parameters that could be adjusted to fit the data.

Figure 9 shows this procedure briefly. The resistance to crack extension R is taken to be a parabola that intersects the abscissa axis at an adjustable position. The curve $\mathcal{G}(\sigma)$ is the value of crack-extension force as a function of $\pi a/W$ with the gross stress σ assumed constant at some value less than the stress for maximum load σ_M. As the crack extends, equality of $\mathcal{G}$ to R requires increasing the value of σ to raise the curve of $\mathcal{G}(\sigma)$. When the curve is raised sufficiently to become tangent to R, crack extension occurs without further increase of σ.

An equation developed from this model with reference to the center-crack specimen was found to satisfy a large and varied body of experimental data:

$$2 \arctan q_2 - \frac{q_2}{1 + q_2^2} = \frac{2\pi a_0}{W} + 2C + \frac{1}{2}\left(\frac{\sigma}{\sigma_{YS}}\right)^2 q_2 \ldots (26)$$

where:

$$q_2 = \frac{(K_{c3})^2}{W\sigma^2}$$

and

$$C = 4.7\,(P - 0.43)\,\frac{B}{W}$$

is an empirical correction term based on the running crack shear-lip fraction P. From Eq 26, in a graph of $\pi a_0/W$ *versus* $(\sigma/\sigma_{YS})^2$, the focus of any fixed value of q_2 is a straight line. A similar situation exists with regard to the edge-notched specimen and a fixed value of q_4. Thus, simple graphical procedures may be employed in calculation of the no-stain K_c-values K_{c3} and K_{c4}.

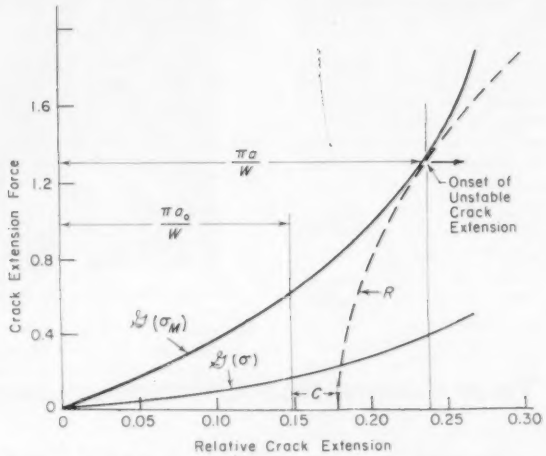


Fig. 9.—Steps leading to unbalance of crack extension force over resistance to crack extension and, thus, to crack growth instability.

APPENDIX

List of Symbols

K	= measure of stress elevation around leading edge of crack.	W	= specimen width.
K_c	= measure of fracture toughness or K-value at point of crack growth instability.	B	= specimen thickness, sheet thickness (specimen (width, Table II).
$\sigma_x, \sigma_y, \tau_{xy}$	= stresses referred to Cartesian coordinates.	σ_M	= maximum stress on the gross section BW for the fracture test.
r, θ	= polar coordinates from leading edge of crack.	σ_N	= average stress on the net section $B\ (W - 2\ a)$ for the maximum load of the fracture test.
$2a$	= crack length.	σ_{YS}	= 0.2 per cent offset tensile yield-strength.
a	= half-length of central crack, depth of edge crack (slow crack length, Table II).	β	= measure of ratio of plastic-zone size to specimen or sheet thickness.
a_0	= notch depth from center line or edge.	q	= stress distribution factor.
E	= Young's modulus.	q_c	= value of q for the maximum load of the fracture test.
$\mathcal{G}_c$	= critical Griffith strain-energy release rate for unstable crack extension.	a_1	= effective half-length of the crack, a, plus the plastic-zone size correction-factor.
σ	= uniform stress across a wide section remote from the crack and normal to the direction of crack extension (gross-section stress at onset of fast fracture, Table II).	σ_{0x}	= stress-field parameter, an added uniform extensional stress in the x-direction.
		P	= per cent shear, (Table II).

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(1) G. R. Irwin, "Fracture-Toughness Testing Procedures for High-Strength Sheet Materials," (forthcoming).

(2) G. R. Irwin, "Fracture Dynamics," *Fracturing of Metals*, Am. Soc. Metals, Cleveland, Ohio (1948).

(3) E. Orowan, "Fundamentals of Brittle Behavior in Metals," Fatigue and Fracture of Metals, Symposium, Massachusetts Institute of Technology, June, 1950, John Wiley & Sons, Inc., New York, N. Y. (1950).

(4) H. Neuber, "Theory of Notch Stresses," Julius Springer, Berlin (1937), Translation No. 74, David Taylor Model Basin, Washington, D. C. (1945).

(5) H. Bernstein and G. C. Young,

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(6) J. E. Srawley and C. D. Beachem, "Crack Propagation Tests of High-Strength Sheet Steels Using Small Specimens," NRL Report 5127, April 9, 1958.
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(10) G. R. Irwin, J. A. Kies, and H. L. Smith, "Fracture Strengths Relative to Onset and Arrest of Crack Propagation," *Proceedings*, Am. Soc. Testing Mats., Vol. 58, p. 640 (1958).
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(12) G. R. Irwin, "Fracture," Springer "Encyclopedia of Physics," Vol. VI, pp. 551–590 (1958).
(13) G. R. Irwin, "Fracture Mechanics," ONR Symposium on Naval Structural Mechanics (Pergamon Press, forthcoming).
(14) G. R. Irwin, "Fracture Mode Transition for a Crack Traversing a Plate," ASME Metals Engineering Division Conference, Albany, N. Y. April 29–May 1, 1959.

Know Your Committee Officers

To better acquaint Bulletin readers with the men who direct the indispensable work of the ASTM technical committees.

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Technical Committee Notes

OFFICERS OF NEW COMMITTEE C-24 ON JOINT SEALANTS

At the organization meeting of the committee, ASTM Headquarters, Sept. 15, 1959 *(left to right, seated)*, H. F. Kleinhans, Pawling Rubber Corp., membership secretary; Wayne F. Koppes, architectural consultant, chairman; J. R. Panek, Thiokol Chemical Corp., secretary; and R. K. Humke, Minnesota Mining and Mfg. Co., vice-chairman. Standing at rear are ASTM Staff members R. E. Hess and L. C. Gilbert.

Leather Exposure Program Ends; Sampling Methods Discussed

Methods of sampling leathers were presented at the meeting of the Joint Committee on Leather, in Philadelphia, Pa., November 13, 1959. These methods include sampling cattle hide upper leather and sampling small skins for physical testing. Other possible methods were also discussed.

Work on mechanical leathers includes a method of area stability of leather in water and oil and final action on a method to determine bond strength of leather belting.

Progress on the development of methods for physical dimensions, tensile properties, water resistance, and surface characteristics was reported.

The extensive program to compare fading characteristics of a variety of pigment-coated leathers under natural and artificial atmospheric exposures has been completed. This work shows that the aggressiveness of exposure in south Florida can be on the order of three times as great in the summer as in the winter. The results also show that the aggressiveness of the laboratory test machines varies from zero to nearly that of south Florida exposure in the winter.

Adhesives Committee Explores Three New Areas

Adhesives for laminated glass, shoes, and flooring applications were three new areas explored at the meeting of Committee D-14 on Adhesives held at Case Institute, Cleveland, Ohio, on November 6, 1959. Current status of adhesives for laminated glass and the need for uniform test methods was presented by Marco Petronio, Frankford Arsenal, Philadelphia, Pa. Testing problems in the shoe adhesive field were reviewed by R. J. Carey, Compo Shoe Machinery Corp., Waltham, Mass., chairman of the new group. Existing tests in the field of adhesives for flooring applications were presented by C. W. Bayley, Borden Chemical Co., Peabody, Mass., committee chairman.

The new Subcommittee on Wood Adhesives has been directing its main effort to refining and re-establishing on a sound research basis the existing standard methods. New work under consideration includes a standard for reading wood failure in plywoods, testing the binder of particle boards, and a method to evaluate adhesives for delamination specimens. One of the many methods reported at the meeting was a test for permanence of adhesive plywood joints under mold conditions. This method, and its variations, have been in use for over 15 years, using controlled and uncontrolled mold conditions. Following many years' experience with a standard inoculum, it has been decided that the molds developed from uncontrolled natural spores occurring in the atmosphere are perfectly satisfactory for testing the effect of molds on plywood shear specimens.

Near completion are standards for peel and cleavage testing, sampling of adhesives, exposure testing, specifications for adhesives for automatic machine sealing and installations of acoustical tile.

COMMITTEE E-11 ON QUALITY CONTROL OF MATERIALS

Members of Committee E-11 are pictured at their November 18 meeting at Society Headquarters. Clockwise around table, starting at near end: Gerald Lieberman, Stanford Univ.; R. B. Murphy, Bell Telephone Laboratories; William R. Pabst, Jr., U. S. Navy Bureau of Ordnance; John Mandel, National Bureau of Standards; Louis Tanner, U. S. Customs Laboratory; P. S. Olmstead, Bell Telephone Laboratories; E. G. Olds, Carnegie Institute of Technology; S. Collier (chairman), Johns-Manville Corp; O. P. Beckwith (acting secretary), The William Carter Co.; H. F. Dodge, Rutgers Univ.; Charles L. Matz, Commonwealth Edison Co.; William P. Goepfert, Aluminum Company of America; D. H. W. Allen, American Iron and Steel Inst.; R. H. Ede, United States Steel Corp.; and C. A. Bicking (vice-chairman), The Carborundum Co. Present at the meeting, but not in the photograph, was Robert J. Hader, North Carolina State College.

Annual Award Announced for Best Paper on Lime

THE NATIONAL Lime Assn. has announced a $1000 Victor J. Azbe Lime Award to be given annually for the best technical paper on lime. Any paper dealing with the manufacture of lime, including plant or equipment design, or with research on its chemical or physical properties, or methods of tests for evaluating its properties and quality, may qualify.

The donor of this award, Victor J. Azbe, president of the Azbe Engineering Corp., Clayton, Mo., has been a consulting engineer specializing in lime manufacture problems and plant design for 40 years and a leader in research and development in connection with lime. Mr. Azbe hopes that this award will stimulate greater interest and more research on lime among chemists and engineers.

The first award will be made in the fall of 1960. All papers should be sub-

mitted by March 1960, to the National Lime Assn., administrator of the contest. The judges, three nationally recognized lime authorities, will be: Nathan C. Rockwood, former editor of *Rock Products;* C. C. Loomis, president of New England Lime Co.; and W. E. Wing, chairman of the board, Marblehead Lime Co. Further details can be obtained from the National Lime Assn., 925 15th St., N. W., Washington, D. C.

Electron Diffraction Data Card File Needed?

To DISCUSS the need for making electron diffraction data more generally accessible to those who need it, a group of about 20 individuals met at the Mellon Inst., in Pittsburgh, Pa., on Nov. 11, 1959. Victor Hicks, Allen-Bradley Corp., presided. The group decided that it would be desirable to prepare compilations of these data in a form similar to the ASTM X-ray diffraction card file.

William Fink, vice-chairman of the Joint Committee on Chemical Analysis by Powder Diffraction Methods, was designated to represent the group at a meeting of the International Union of Crystallography in Cambridge, England, in Aug., 1960, and to present the problem to the international group concerned.

The group solicits comments from all those interested, so that it can gage the extent of the interest in this project. You are invited to send your comments to Karl E. Beu, Goodyear Atomic Corp., P. O. Box 628, Portsmouth, Ohio, before July 1, 1960.

COMING DISTRICT MEETINGS

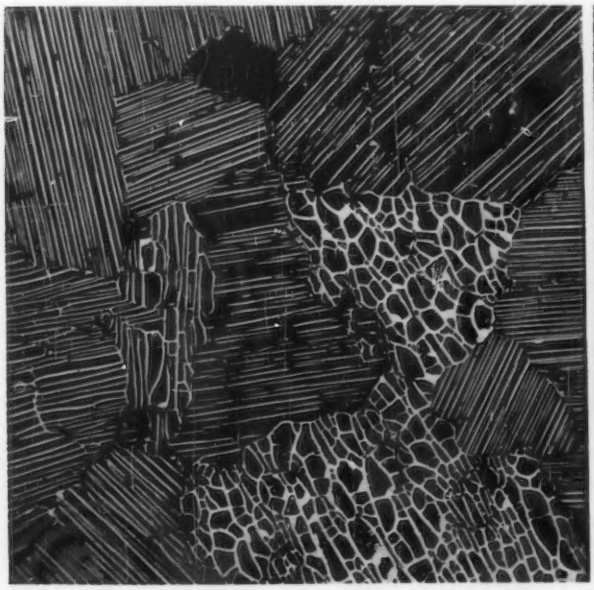
Date	District	Place	Speaker
January 26	Southeast	Atlanta	F. L. LaQue
January 27	New York	New York	F. L. LaQue
February 9	Southwest	Houston	F. L. LaQue
February 11	Southwest	Dallas	F. L. LaQue
February 16	Washington	Washington, D. C.	F. L. LaQue

1959 SES-ASTM Awards

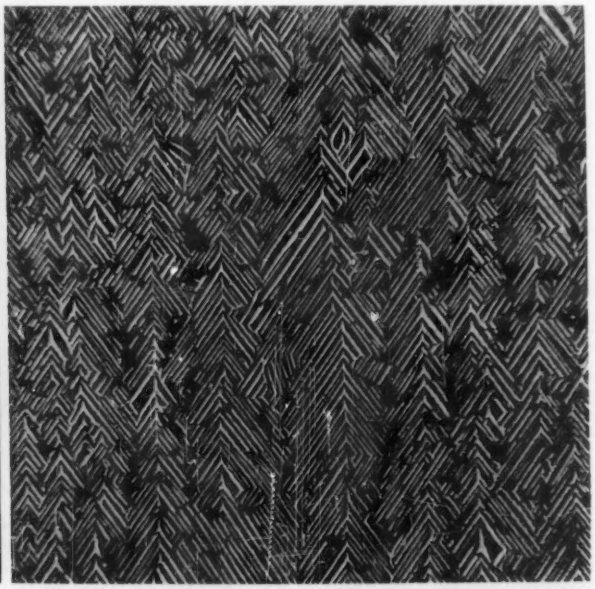
AT THE Eighth Annual Meeting of the Standards Engineers Society, in Boston, Sept. 22, 1959, two awards, jointly sponsored by SES and ASTM, were presented. An award for outstanding service in standardization was presented to Willis S. MacLeod. The second award, for outstanding contributions to the literature on standards, was presented to Samuel P. Kaidanovsky.

The citation on the award for Mr. MacLeod, director of the Standardization Div., General Services Administration, Federal Supply Service, read in part: "For his outstanding service in the interest of general standardization, with particular reference to government and industry coordination of standards..." During World War II, Mr. MacLeod served with the Office of Civilian Requirements, War Production Board; he then became director of the Standards Div., Office of Price Administration. His industrial experience has been with Standard Oil Co., N. J., and with the Standard Oil Development Co.

Although Mr. Kaidanovsky has contributed to a number of periodicals, including *Magazine of Standards* and *Standards Engineering*, he was cited particularly for a series of six articles, "Guide to Materials Standards and Specifications," that he prepared in 1958 for *Materials in Design Engineering*. Mr. Kaidanovsky has served as chief, Standards Unit, National Recovery Administration, and later became head of the Consumer Standards Branch of the U. S. Department of Agriculture. He has also served as chairman of the Federal Interdepartmental Standards Council. He founded, and for two years edited *Standard World* magazine.



ORIENTATION OF RANDOM GRAINS REVEALED BY FILM CRACKING



ORIENTATION OF TWIN-COLUMNAR GRAINS REVEALED BY FILM CRACKING

This micrograph was prepared by etching a metallographically polished specimen of 7070 alloy ingot until a black film was produced, after which the film was blown dry quickly. The pattern of cracking is related to the orientation of each grain. Third Prize Photomicrographs, Black and White—Methods; Eleventh ASTM Photographic Exhibit. Glenn R. Frank, Jr., Aluminum Co. of America, New Kensington, Pa.

A Study of the Accelerated Aging of Vinyl Plastic Compounds in a Modified Testing Oven*

By MARKUS ROYEN

The aging properties of poly(vinyl chloride) compounds are largely dependent on the type and proportion of plasticizers which they contain. Aging is a complex process involving, among other things, an accelerated migration of plasticizers to the surface of the material and subsequent evaporation. Even though the polymer itself remains basically unchanged, this loss of plasticizers causes a distinct change in the properties of the material. Therefore aging tests are commonly a part of specifications for PVC compounds.

Extensive work by many companies has shown that present standard methods for evaluating heat aging of PVC compounds are not reproducible. This paper describes work which confirms these conclusions. A new oven design is proposed which provides reproducible heat aging of PVC compounds.

Most aging methods at present require the use of "forced air mechanical convection ovens." In recent years it was recognized that air flow over the specimens during the aging test has a decisive effect on properties of the material because of removal of volatiles. These presently adapted procedures, in listing aging test conditions precisely specify the temperature and the time but not the air flow. A possibility is thus created for nonuniformity in one of the vital factors of the test, which consequently produces results that cannot be safely reproduced. The procedure described here introduces a precisely specified air-flow value in feet per minute, which supplements the present test requirements and makes it possible to solve the problem of uniformity and reproducibility. Three characteristics of air flow can be considered important: (1) rate, (2) relation to the position of sample, and (3) degree of contamination with volatile components of the test sample.

Rate

Graves (1)[1] has observed that little attention has been paid to control of the amount of fresh air supplied to the oven and to the rate of air flow over the specimens. According to Graves' studies of air flow in several mechanical convection ovens, both with vertical and horizontal flow, it has been found in almost all cases that even in the center of the testing chamber, there are areas of very high air velocity, due primarily to design, adjacent to areas where the air is moving slowly, sometimes even in the opposite direction of the expected flow.

Sample Position

The position of the sample subjected to air flow should be such as to expose uniformly its whole surface to the flow and, at the same time, not to obstruct the flow unduly. This position must be maintained throughout the test period.

Contamination

In studying loss of plasticizer in vinyl plastics, it was noted that in the same oven the plasticizer apparently migrated from one specimen to another having less plasticizer, although the two specimens were not touching each other. It was also noted that the rate of plasticizer loss of a given material, when heated, is not uniform and depends on the rate of flow and also on the purity of the surrounding air. The phenomena of the rate of cross-migration and uniform rate of volatility, depending upon the dissimilarity of concentration or vapor pressures of the materials involved in adjoining media, are known and explained by physical laws.

The concept of air-flow control is not new, nor are ovens designed to prevent cross-migration of volatile constituents. Enjay Laboratories worked on units to accomplish such purposes. An oven of this type is described in the Tentative Specification For Cell Type Oven With Controlled Rates of Ventilation (E 95-58T).[2] Raine (2) in England, has described a similar type apparatus. The Australians have developed ovens which provide control of air flow. These reports indicate that the effect of air flow on the aging reproducibility problem is widely recognized.

The problem of testing vinyl compounds for heat aging has been aggravated in recent years by the trend toward higher aging temperatures as product requirements get more demanding. For the past year a Task Group on Oven Aging of Plasticized Poly(vinyl Chloride) and Highly Plasticized Elastomers, (Joint D-20/D-11—ASTM Committees on Plastics and on Rubber), has made systematic studies of aging of vinyl plastics in an attempt to arrive at a reproducible method. Recognition of this problem is summed up in the conclusion of the Committees recent progress report which states, "results obtained in the two round-robin tests have shown conclusively that the present oven-aging procedure is not satisfactory."

NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

* Presented at the Sixty-second Annual Meeting of ASTM, before a Joint Meeting of Committees D-11 on Rubber and D-20 on Plastics, Atlantic City, N. J., June 25, 1959, and with supplementary information at the Annual Convention of the Wire Assn. in Cleveland, Ohio, Oct. 14, 1959.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

[2] ASTM Specification for Cell-Type Oven with Controlled Rates of Ventilation (Tentative) (E 95-58 T), 1958 Book of ASTM Standards, Part 6, p. 947; Part 8, p. 1491; Part 9, p. 1867.

M. ROYEN received his masters degree in chemical engineering in 1925 from the Institute of Technology in Danzig, Germany. He did post graduate work at the Univ. of Berlin, Charlottenburg. He initiated his professional career as a chemist at Anglo-Polish Rubber Manufacturers, Gentlemen, Ltd., the largest rubber company in Poland. After several years he became technical director of this company. He came to the U. S. in 1941 and became engaged with research work on synthetic rubbers. In 1945, he joined the Apex Tire & Rubber Co., where at present he is covering the position of research director. In the PVC field his activities cover many phases of production, research, and development. In 1958 he was appointed a vice-president of the company.

From the beginning, the objective of the work described here was to develop a test system that was both practical and reproducible. This was needed both for laboratory work in compound development and for product control. Studies were conducted with electrical insulation compounds in every-day use in the wire and cable industry. This work is described in four specific phases as follows:

1. An investigation of uniformity of heat aging of PVC compounds in present ovens with present methods,
2. A description of a practical modification of the conventional heat-aging oven,
3. An investigation of the uniformity of heat aging of PVC compounds in the modified oven, and
4. The determination of duplicability of results from several ovens so modified.

Study of Uniformity of Heat Aging of PVC Compounds According to Present Methods, D 573-53[3]

Preliminary Tests

A round of tests by Underwriters' Laboratories, Inc., by the American Insulated Wire Co., and by Apex Tire and Rubber Co. was initiated to determine the degree of duplication obtainable through use of present equipment and procedures.

For these tests, UL acceptable, but marginal, compounds were selected to emphasize differences. It was recognized that better aging compounds would minimize differences because of less critical behavior during the oven tests. The compounds selected were identified as follows:

Compounds 1 and 1A . . . . . typical TW materials
Compounds 2 and 3 . . . . . typical SPT materials

Test specimens 45 mils thick were all cut from the same batch sheet, each set comprising six samples. All samples were aged seven days at 100 C, then tested for physical characteristics by ASTM method D 412.[4]

Table I shows that results from three laboratories for tests conducted under supposedly identical conditions and according to methods described by ASTM for the electrical industry, D 412, cannot in any way be considered equivalent.

To supplement this study, specimens were tested by Apex under five different air-flow conditions. All were conducted in the same oven with specimens placed in identical locations, with a fully opened air exhaust, and a different setting of air-intake valve for each test.

From the data in Table II the following conclusion can be drawn: higher rates of air flow result in more severe aging. By comparing the results of tests by Apex Laboratories with those obtained by Underwriters' Laboratories' Inc., it may be seen that air intake opening No. 3 could be considered the closest equivalent to the Underwriters' Laboratories testing conditions. Air intake opening No. 2 produced results closest to those obtained by the American Insulated Wire Co.

In view of these observations air intake opening No. 3, the more critical, was selected as a fixed setting for subsequent testing.

TABLE I.—A COMPARISON OF TESTS BY THREE LABORATORIES.

	Compound	Laboratories		
		a	*b*	*c*
1	Elongation retention, per cent	30	50	20–76
	Tensile retention, per cent	109	105	100–128
2	Elongation retention, per cent	57	87	60–92
	Tensile retention, per cent	99	98	103–110
3	Elongation retention, per cent	73	67	40–89
	Tensile retention, per cent	105	88	100–110

[a] Underwriters' Laboratories, Inc.
[b] American Insulated Wire Co.
[c] Apex Tire and Rubber Co. The range of values for these tests resulted from tests at various oven settings (see Table II).

TABLE II.—THE EFFECT OF AIR FLOW VARIATION IN AN UNMODIFIED OVEN.

	Intake Air Valve Setting	Compound		
		No. 1	No. 2	No. 3
1	Elongation retention, per cent	76	92	89
	Tensile retention, per cent	100	103	100
	Weight loss, per cent	10.3	3.8	5–7
2	Elongation retention, per cent	56	86	82
	Tensile retention, per cent	104	105	110
	Weight loss, per cent	11.4	3.9	6.8
3	Elongation retention, per cent	26	71	56
	Tensile retention, per cent	105	106	103
	Weight loss, per cent	14.3	9.8	10.5
4	Elongation retention, per cent	20	68	44
	Tensile retention, per cent	128	110	100
	Weight loss, per cent	16.7	11.4	12.3
5	Elongation retention, per cent	26	60	40
	Tensile retention, per cent	111	107	103
	Weight loss, per cent	14.7	10.9	12.0

TABLE III.—PERFORMANCE IN UNMODIFIED OVEN TEST NO. 2.

	Oven Positions	1	2	3	4	5	6	Average
Elongation retention, per cent	A	74	71	76	84	82	68	76
Tensile retention, per cent	A	98	98	95	100	100	105	99
Weight loss, per cent	A	8.0	8.3	8.2	7.7	7.4	11.6	8.8
Elongation retention, per cent	B	82	79	82	79	71	63	76
Tensile retention, per cent	B	100	102	103	98	106	109	103
Weight loss, per cent	B	8.3	9.0	8.5	9.1	10.8	13.7	10.0
Elongation retention, per cent	C	82	76	79	74	74	48	72
Tensile retention, per cent	C	100	106	106	106	109	109	106
Weight loss, per cent	C	8.5	9.3	10.6	11.7	12.4	15.0	11.0
Elongation retention, per cent	D	84	76	74	74	74	55	73
Tensile retention, per cent	D	100	100	97	100	105	110	102
Weight loss, per cent	D	7.7	10.6	8.6	10.0	11.3	15.1	10.3
Elongation retention, per cent	E	84	79	76	79	74	58	75
Tensile retention, per cent	E	98	95	95	103	105	109	101
Weight loss, per cent	E	7.3	7.3	7.3	8.5	10.3	14.2	9.2
Elongation retention, per cent	F	82	79	79	84	79	58	77
Tensile retention, per cent	F	95	95	94	103	105	109	100
Weight loss, per cent	F	5.7	6.5	6.5	7.6	9.8	14.3	8.3
Elongation retention, per cent	Average	81	77	78	79	76	59	75
Tensile retention, per cent	Average	99	99	98	102	105	109	102
Weight loss, per cent	Average	7.6	8.5	8.3	9.1	10.2	14.0	9.6

TABLE IV.—SUMMARY TEST NO. 2.

Test	Average	Variations
Elongation retention, per cent	75	48 to 84
Tensile retention, per cent	102	94 to 110
Weight loss, per cent	9.6	5.7 to 15.1

Effect of Specimen Position

In the preliminary tests there had been no specification as to position of the specimens in the ovens. Further, variation in the rate of air flow at a fixed setting of the oven valves was known to exist within the ovens. This is significant with respect to the influence of air-

[3] ASTM Method of Test for Accelerated Aging of Vulcanized Rubber by the Oven Method, 1958 Book of ASTM Standards, Part 9, p. 1385.
[4] ASTM Method of Tension Testing of Vulcanized Rubber (Tentative) (D 412-51 T), 1958 Book of ASTM Standards, Part 9, p. 1361.

flow rate. This led to a study of the relationship of specimen position to severity of aging and duplication of results.

The oven employed was a precision Scientific Co. Catalogue No. 31058 unit with a 19 by 19 by 19-in. chamber. The shelf of this oven was divided equally into 49 squares, which covered the entire shelf area (Fig. 1).

Results for test No. 2 selected as typical, are presented in Tables III and V and are summarized in Table IV. Each block of data in the tables represents a specific position within the oven. Those on the bottom right side are nearest the air inlet (B-6, C-6, etc.); those on the bottom row, nearest the door (F-1, F-2, etc.). These data point out a tremendous variation of aging severity within the oven. Variations are particularly evident in plots of data shown in Figs. 2, 3, and 4.

Figure 2 is a plot of data from row C of Table III. This is typical of results in rows lying parallel to air flow. There is substantial variation in aging within the row with greatest severity encountered at the air inlet side. This is particularly apparent in the elongation and weight-loss data. The latter is plasticizer loss, which is greatly influenced by rate of air movement over the specimen.

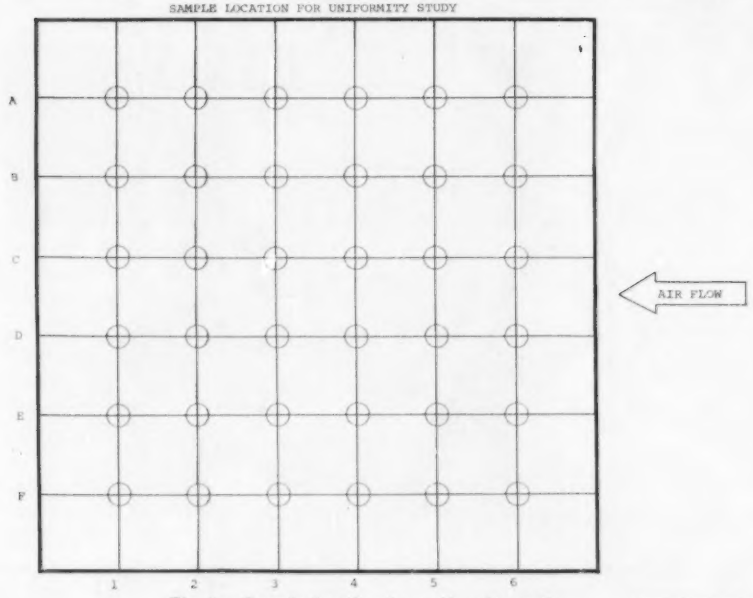


Fig. 1.—Sample location for uniformity study.

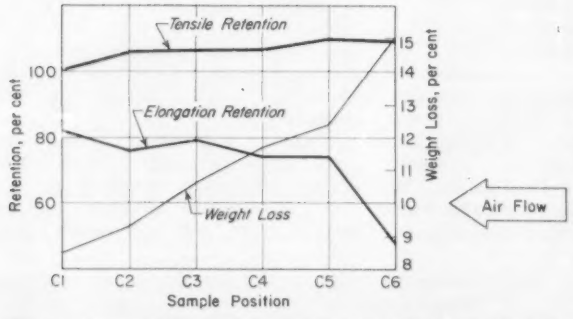


Fig. 2.—Oven performance in unmodified test No. 2 in row C parallel to air flow.

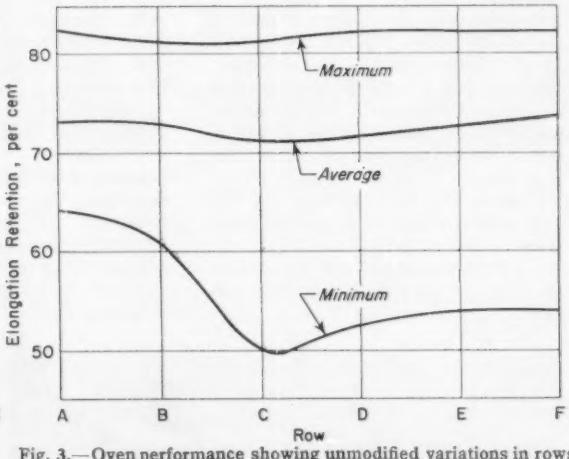


Fig. 3.—Oven performance showing unmodified variations in rows parallel to air flow.

These data can be analyzed on the basis of performance of the series of specimens that hung in rows parallel to the direction of air flow (Fig. 3).

(1) There is a substantial variation in the severity of aging in each row, as indicated by elongation retention, with the greatest aging occurring nearest the air inlet.

(2) There is a relative uniformity of average values of elongation retention in each row. However, the deviations within each row are great and appear to increase near the oven center.

Data from specimens hung in rows perpendicular to the direction of air flow are plotted in Fig. 4.

(1) There is substantial variation in aging conditions within each row perpendicular to air flow, as indicated by all retention and weight-loss values.

(2) There is substantial variation in the average values between rows perpendicular to the air flow, and these data show more clearly the gradual change in severity of aging as the distance from the air inlet is decreased.

Such tests have been conducted repeatedly with similar results. The summary of the two tests illustrated, which were conducted with the same batch of the same compound, shows that even over-all averages can be different on different days. The deviations indicated are beyond anything possible within the compound, especially since all specimens are from a single batch, cut in a planned manner from a single sheet.

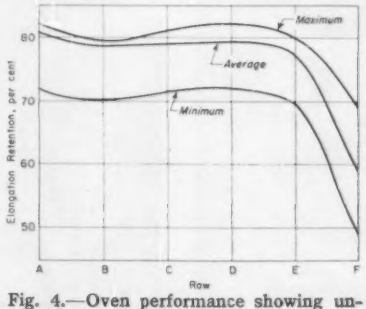


Fig. 4.—Oven performance showing unmodified aging variations in rows perpendicular to air flow.

No tests were made to determine differences at different levels in the oven. However, it is to be expected that variations in flow and turbulence of the air exist also in various vertical planes.

From this work it was concluded that reliability in this test could be achieved

only by loading a number of specimens of the same material uniformly throughout the whole horizontal area of the oven, and then computing the average of all values obtained. This is obviously impractical.

Thus, it was concluded that this method is not satisfactorily reproducible and therefore, not reliable as a means for heat aging PVC compounds.

It is believed that this method is in current use throughout the industry. It is the method which the ASTM Task Group of Committees D-11 and D-20 has recently rejected.

A Description of a Practical Modification of the Conventional Heat-Aging Oven

It was apparent that a procedure should be devised to enable the placement of samples in any position in the oven, and, if possible, without interference with each other. A system to permit control of air flow throughout the oven was needed in order to provide the necessary uniform and predictable testing conditions.

The air-flow variation was particularly evident from the behavior of the specimens in the series just reviewed: some specimens waved gently, others were in currents so strong as to lift them almost to horizontal positions, while others were completely quiet.

Our work has shown the temperature uniformity within the oven to be adequate. In fact, it has been definitely established by several investigators that equipment for use in the ASTM method provides satisfactory reproducibility in respect to the temperature control factor.

Thus it was desirable that any new oven design meet the following objectives:

1. Controllable and uniform air flow over the specimen with minimum turbulence,

TABLE V.—OVEN PERFORMANCE, UNMODIFIED AGING VARIATIONS IN ENTIRE TEST AREA.

	Test No. 2			Test No. 3		
	Minimum	Maximum	Average for 36	Minimum	Maximum	Average for 36
Elongation retention, per cent	48	84	75	51	84	68
Tensile retention, per cent	94	110	102	90	108	98
Weight loss, per cent	5.7	15.1	9.6	5.8	14.9	9.4

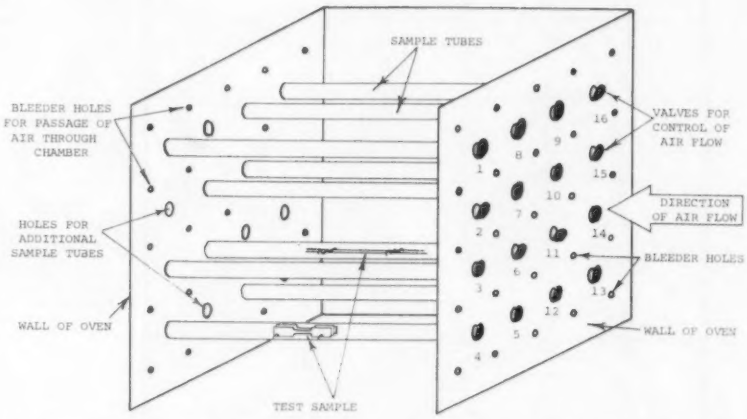


Fig. 5.—Tubular modification unit for conventional oven used in Apex tubular oven.

2. Simple adjustment of temperature and air flow conditions,
3. Specimen isolation to eliminate contamination, and
4. Practical and economical adaptation of existing equipment.

These objectives were achieved with a tubular oven, as shown in Fig. 5. The unit is designed for insertion in standard ovens which are provided with removable sidewalls. The most widely used ovens today have this feature, and thus are adaptable to modification. The unit consists of two replacement walls. The walls are heavy gage, rigid aluminum sheets provided with machined holes and attached clips to accommodate the specimen tubes. The air entrance wall, in addition, is provided with vents for each tube position. These vents are individually adjustable from within the oven for predetermined setting of the air velocity in feet per minute. Both walls are provided with machined openings to permit passage of air outside the glass tubes for over-all temperature uniformity.

Figures 6 and 7 show an Apex oven under actual operating conditions. The closer view illustrates specimen positioning. Holders are designed for insertion in the tube and simple quick

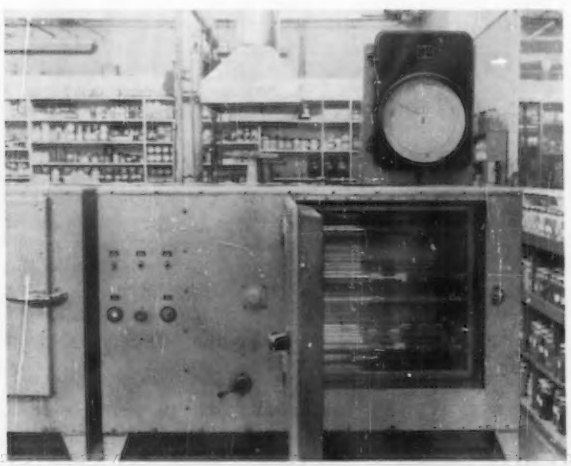


Fig. 6.—Apex oven under actual operating conditions.

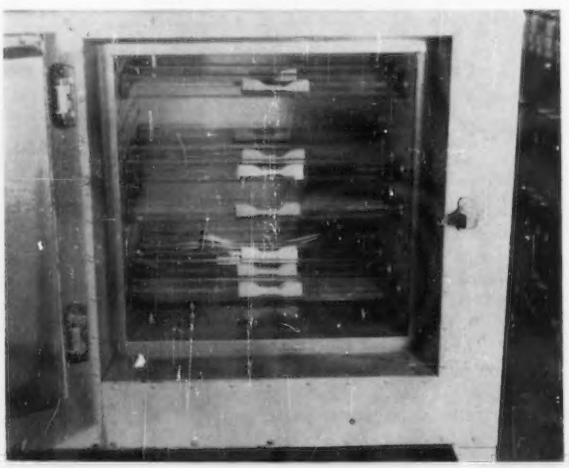


Fig. 7.—Closer view of oven showing sample positioning.

change of specimen. Significant to the uniformity of results obtained is the fact that these holders permit essentially no movement or swinging of the specimen during exposure. Further, they position the specimen in such manner that the flow of heated air is

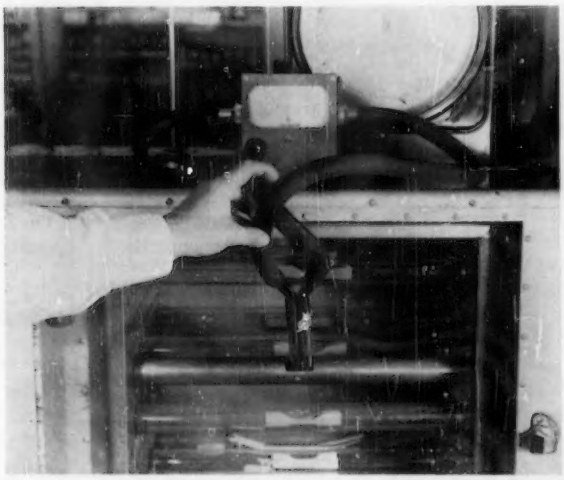


Fig. 8.—Apparatus used in presetting the specific rate of air flow within the tubes.

in a direction parallel to their longitudinal axis, a close approximation to conductors in a conduit. The tube placement pattern shown permits the convenient removal of a single tube at any time. This feature limits the number of tubes in the oven cavity. For instance, the standard 19 by 19 by 19-in. oven cavity with this design holds 16 tubes or 48 specimens.

Auxiliary to the unit itself is the apparatus used in presetting the specific rate of air flow within the tubes. This consists of a tube (Fig. 8) of dimensions equal to the specimen tubes. For practical purposes it is made of metal. The tube is provided with a 1.75 by 0.625-in. slot to permit insertion of the probe of a velometer.

Before testing, air flow through each tube must be adjusted to a predetermined value. To adjust rate of air flow, the special tube is inserted in place of one of the oven tubes. With the oven at the temperature of test and with the intake and exhaust valves and damper preset, the air velocity through the tube is measured by inserting the probe of an Almor velometer in the tube opening, and is set to the desired fpm rate by adjustment of the baffles. This procedure is continued with each tube (Fig. 9).

This is not a complicated operation. It was found that velocities within the tubes, once set, will remain constant, for extended periods, so long as the oven intake valve is not changed. Periodic check, however, is routine procedure.

Uniformity of Heat Aging PVC Compounds in the Apex Tubular Oven

Certain preliminary tests and calibrations were necessary before any tests of duplicability could be conducted. These consisted of establishment of air-flow rate, and the best position of the specimen in the tube.

Establishment of Air-Flow Rate

This work was done with compound No. 1, and aging was conducted at var-

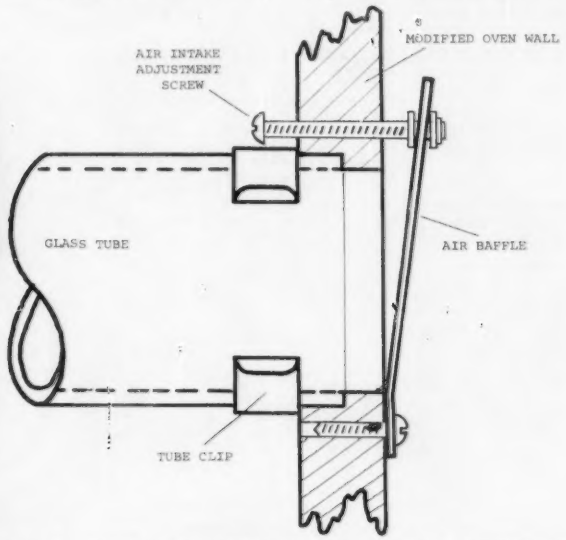


Fig. 9.—Detail of the variable vent assemble in the Apex tubular oven.

TABLE VI.—TUBULAR OVEN EFFECT OF AIR FLOW VARIATION.

Tube Number	1	2	4	5	6
Air Flow, fpm	200	300	400	500	600
Elongation retention, per cent	89	79	75	72	69
Tensile retention, per cent	108	107	108	108	108
Weight loss, per cent	11.4	12.9	13.9	14.5	15.1

TABLE VII.—EFFECT OF SPECIMEN POSITION, 7 DAYS, 100 C, 400 FPM.

Tube Number		2			5	
Position of Specimen	Left	Center	Right	Left	Center	Right
Elongation retention, per cent	83	72	63	78	73	..
Tensile retention, per cent	105	105	107	106	107	..
Weight loss, per cent	12.4	13.2	14.6	13.8	14.7	..
Tube Number		10			11	
Position of Specimen	Left	Center	Right	Left	Center	Right
Elongation retention, per cent	80	74	63	86	74	71
Tensile retention, per cent	101	106	106	104	104	104
Weight loss, per cent	13.7	14.5	15.5	13.1	13.6	14.8

TABLE VIII.—PERFORMANCE IN THE TUBULAR OVEN, 7 DAYS, 100 C, 400 FPM.

Tube Number	1	2	4	5	6
Elongation retention, per cent	76	72	78	73	76
Tensile retention, per cent	106	105	106	107	105
Weight loss, per cent	14.1	13.2	14.3	14.7	14.3
Tube Number	10	11	13	16	Average
Elongation retention, per cent	74	74	75	78	75
Tensile retention, per cent	106	104	106	105	106
Weight loss, per cent	14.5	13.6	14.4	14.2	14.1

TABLE IX.—PERFORMANCE IN THE TUBULAR OVEN, 7 DAYS, 100 C, 400 FPM.

Tube Number	3	4	5	6	11	12
Elongation retention, per cent	76	79	78	75	78	75
Tensile retention, per cent	107	107	107	106	108	107
Weight loss, per cent	13.8	13.5	13.6	13.8	13.7	13.9
Tube Number	13	14	Minimum	Maximum		Average
Elongation retention, per cent	75	76	75	79		76
Tensile retention, per cent	107	107	106	108		107
Weight loss, per cent	13.9	13.8	13.5	13.9		13.8

TABLE X.—PERFORMANCE IN THE TUBULAR OVEN, 7 DAYS, 100 C, 400 FPM.

Tube Number	3	4	5	6	11	12
Elongation retention, per cent	75	75	75	76	72	72
Tensile retention, per cent	103	103	103	103	105	104
Weight loss, per cent	13.5	13.6	13.5	14.0	13.8	13.8

Tube Number	13	14	Minimum	Maximum	Average
Elongation retention, per cent	72	72	72	76	74
Tensile retention, per cent	104	104	103	105	103
Weight loss, per cent	14.1	13.8	13.5	14.0	13.8

TABLE XI.—PERFORMANCE IN THE TUBULAR OVEN, 7 DAYS, 100 C, 400 FPM.

Tube Number	1	2	3	4	5
Elongation retention, per cent	78	78	78	81	77
Tensile retention, per cent	108	107	106	103	103
Weight loss, per cent	13.7	13.5	13.5	13.3	13.6

Tube Number	6	7	8	9	10
Elongation retention, per cent	75	75	78	78	75
Tensile retention, per cent	105	106	105	106	106
Weight loss, per cent	13.7	13.9	13.7	13.6	13.9

Tube Number	11	12	13	14	15
Elongation retention, per cent	75	77	75	75	78
Tensile retention, per cent	107	106	103	104	105
Weight loss, per cent	14.0	13.8	13.9	13.6	13.5

Tube Number	16	Minimum	Maximum	Average
Elongation retention, per cent	80	75	81	77
Tensile retention, per cent	105	103	108	105
Weight loss, per cent	13.5	13.3	14.0	13.7

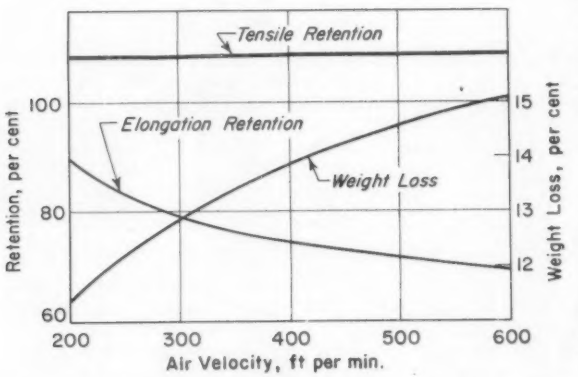


Fig. 10.—Results show severity of aging increases directly with velocity of air over specimen.

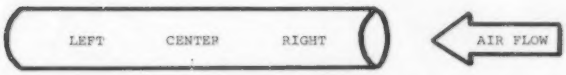


Fig. 11.—Three positions of air samples.

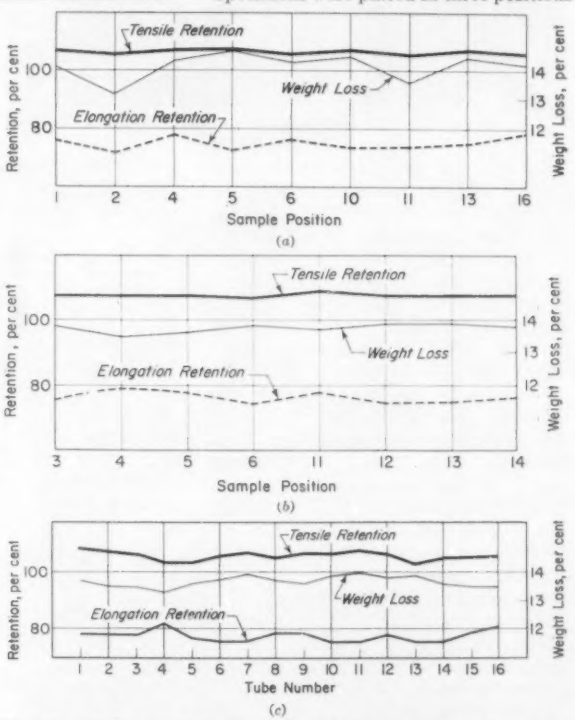


Fig. 12.—Performance in the Apex tubular oven showing various tests. (*a*) Table VIII, (*b*) Table IX, (*c*) Table XI.

TABLE XII.—TUBULAR OVEN COMPARISON FOR COMPOUND A, 7 DAYS, 100 C, 400 FPM.

Tube Number	1	3	5	7	Average
Oven Number 1					
Elongation retention, per cent	91	89	89	86	89
Tensile retention, per cent	105	105	105	105	105
Weight loss, per cent	5.4	5.9	6.0	5.9	5.8
Oven Number 2					
Elongation retention, per cent	88	88	84	88	88
Tensile retention, per cent	103	104	104	105	104
Weight loss, per cent	5.8	5.9	8.0	5.7	5.8

ious predetermined air velocities. Results are shown in Table VI.

First of all, this test verifies the fact that severity of aging increases as velocity of air passing over the sample increases. It must be realized that this is quite significant since never before to our knowledge has any specification been set on control of air flow in measurable units during the aging test. For further work, the velocity value of 400 fpm was selected for the following reasons: (1) the drop in elongation was observed to settle to a steady state, about 3 per cent per 100 fpm above 300 fpm (Fig. 10); (2) the results at 400 fpm indicated a correspondence with the average value obtained for this compound in the oven test described in Table III; (3) UL average retention values for this compound, tested over a period of several years have been of similar magnitude.

Position of Specimens in Tubes

This work was done with compound No. 1 and an air flow of 400 fpm. Specimens were placed in three positions shown in Fig. 11.

A series of tests was run, the results of which are shown in Table VII.

These data showed that an acceptable uniformity between a group of specimens tested in one oven had been achieved. This particular uniformity is evident when one examines in comparison the values in the center position of each tube. Because of these results, the center position was selected for oven

TABLE XIII.—TUBULAR OVEN COMPARISON FOR COMPOUND 4, 7 DAYS, 100 C, 400 FPM.

Tube Number	9	11	13	14	Average
OVEN NUMBER 1					
Elongation retention, per cent	89	88	86	88	88
Tensile retention, per cent	109	108	110	108	108
Weight loss, per cent	13.0	13.4	13.3	13.3	13.3
OVEN NUMBER 2					
Elongation retention, per cent	84	84	88	86	85
Tensile retention, per cent	111	109	109	109	109
Weight loss, per cent	13.6	13.5	13.6	13.4	13.5

TABLE XIV.—TUBULAR OVEN COMPARISON FOR COMPOUND NO. 1-A, 7 DAYS 100 C, 400 FPM.

Tube Number	2	4	6	8	10	Average
OVEN NUMBER 1						
Elongation retention, per cent	83	79	82	83	83	82
Tensile retention, per cent	105	106	107	106	106	106
Weight loss, per cent	11.9	11.8	11.8	12.0	11.7	11.8
OVEN NUMBER 2						
Elongation retention, per cent	82	79	83	82	82	82
Tensile retention, per cent	107	107	106	106	107	107
Weight loss, per cent	11.8	12.3	12.0	11.9	12.2	12.0

TABLE XV.—TUBULAR OVEN COMPARISON FOR COMPOUND NO. 5, 7 DAYS, 121 C, 400 FPM.

Thickness	0.045 in.				0.017 in.			
Tube Number	9	11	14	Average	10	15	16	Average
OVEN NUMBER 2								
Elongation retention, per cent	89	89	89	89	76	79	75	76
Tensile retention, per cent	102	102	102	102	105	109	105	106
Weight loss, per cent	4.1	4.0	4.0	4.0	8.0	8.2	8.0	8.0
OVEN NUMBER 3								
Elongation retention, per cent	86	88	86	86	75	79	76	77
Tensile retention, per cent	103	102	103	102	107	107	106	107
Weight loss, per cent	4.3	3.9	4.1	4.1	8.2	7.8	8.1	8.0

TABLE XVI.—COMPARISON OF TUBULAR OVENS AT DIFFERENT AIR VELOCITIES FOR COMPOUND NO. 5, 7 DAYS, 121 C.

Tube Number	2	7	Average	3	6	Average	4	5	Average
Air Flow, ft per min		400			600			800	
OVEN NUMBER 2									
Elongation retention, per cent	86	88	87	86	83	85	83	80	82
Tensile retention, per cent	102	100	101	103	103	103	105	104	104
Weight loss, per cent	3.6	3.5	3.55	5.1	4.9	5.0	5.5	5.8	5.65
OVEN NUMBER 3									
Elongation retention, per cent	88	86	87	83	82	82	77	82	79
Tensile retention, per cent	102	102	102	105	105	105	106	106	106
Weight loss, per cent	3.6	3.6	3.6	5.5	5.0	5.25	5.7	5.6	5.56

TABLE XVII.—COMPARISON OF TUBULAR OVENS AT DIFFERENT AIR VELOCITIES FOR COMPOUND NO. 6, 7 DAYS, 121 C.

Tube Number	2	7	Average	3	6	Average	4	5	Average
Air Flow, ft per min		400			600			800	
OVEN NUMBER 2									
Elongation retention, per cent	80	83	81	80	83	81	71	69	70
Tensile retention, per cent	105	105	105	106	106	106	108	109	108
Weight loss, per cent	8.1	7.6	7.8	8.9	8.5	8.7	9.6	9.8	9.7
OVEN NUMBER 3									
Elongation retention, per cent	79	83	81	76	77	76	66	66	66
Tensile retention, per cent	105	106	105	105	107	106	110	110	110
Weight loss, per cent	8.1	7.7	7.95	8.4	8.8	8.6	10.1	10.3	10.2

TABLE XVIII.—COMPARISON OF TUBULAR OVENS IN THE AGING OF EXTRUDED VINYL INSULATION FOR COMPOUND NO. 1-A, $\frac{1}{32}$ IN. INSULATION STRIPPED FROM NUMBER 14 SOLID COPPER CONDUCTOR, 7 DAYS, 100 C, 400 FPM.

Tube Number	1	8	9	15	16	Average
OVEN NUMBER 1						
Elongation retention, per cent	84	83	85	83	83	84
Tensile retention, per cent	104	104	104	103	104	104
Weight loss, per cent	14.6	14.2	14.6	14.7	14.8	14.6
OVEN NUMBER 2						
Elongation retention, per cent	85	80	84	84	79	83
Tensile retention, per cent	103	104	104	104	104	104
Weight loss, per cent	14.6	14.7	14.4	14.8	14.8	14.6
OVEN NUMBER 3						
Elongation retention, per cent	75	78	75	79	79	77
Tensile retention, per cent	106	105	104	104	104	105
Weight loss, per cent	15.5	15.2	15.6	14.7	15	15.2

TABLE XIX.—COMPARISON OF TUBULAR OVENS IN THE AGING OF EXTRUDED VINYL INSULATION FOR COMPOUND NO. 7, $\frac{1}{32}$ IN. INSULATION STRIPPED FROM NUMBER 14 SOLID COPPER CONDUCTOR, 7 DAYS, 113 C, 400 FPM.

Tube Number	2	7	10	15	Average
OVEN NUMBER 1					
Elongation retention, per cent	91	90	91	91	91
Tensile retention, per cent	111	110	110	111	111
Weight loss, per cent	9.6	9.5	9.3	9.5	9.5
OVEN NUMBER 2					
Elongation retention, per cent	91	90	93	91	91
Tensile retention, per cent	111	110	110	110	110
Weight loss, per cent	9.1	9.1	9.1	9.0	9.1
OVEN NUMBER 3					
Elongation retention, per cent	89	90	89	91	90
Tensile retention, per cent	108	111	111	110	110
Weight loss, per cent	9.5	9.8	9.6	9.5	9.6

evaluation tests.

With this information conditions were set for a series of repeat tests to determine the ability of the Apex tubular oven to reproduce aging conditions on PVC compounds.

Compound tested...No. 1 from a single batch
Test temperature...100 deg Cent.
Exposure duration..7 days
Air flow.....400 fpm
Sample thickness...0.045 in.
Sample position....Tube center

Tables VIII to XI show the results of duplication tests conducted over a period of time.

It did not seem to matter whether or not all sixteen tubes were used; the aging of the compound was consistent (Figs. 12(*a*), (*b*), and (*c*)).

Determination of Duplicability of Results Between Different Apex Tubular Ovens

The work described had proved only that a single oven could be set up to duplicate itself. The work was extended to determine whether or not several tubular ovens could test the compound under the same conditions with comparable reproducibility. The test series that was planned had several objectives: (1) determine the ability of different ovens to duplicate aging conditions, (2) evaluate more than one compound type in a single oven to determine whether simultaneous testing would interfere with aging reproducibility, and (3) determine whether a significant specimen change would be equally detected by different ovens.

Three ovens were modified with the tubular unit and used for this work. The following tables cover tests in these three ovens on four different compounds. All specimens in the comparison of ovens 1 and 2 were aged simultaneously. The following typical commercial compounds were used for this evaluation:

Compound 4..typical SPT material
Compound 5..typical THW material
Compound 6..typical 90 C, TW material
Compound 7..typical 80 C, TW material

Tables XII, XIII, and XIV show the ability of each oven to reproduce aging conditions in its various tubes (read horizontally), and the ability of different ovens to provide equivalent aging conditions (read vertically). Note the acceptable uniformity between ovens even in the critical elongation-retention and weight-loss properties. It would appear that uniformity is possible even when different compounds are tested simultaneously.

Tables XV, XVI and XVII show the evaluation of reproducibility at various temperatures and air flows.

The data of Table XV bring out another point. Different ovens will detect equally a change in specimen thickness. First, note the drop in properties for the thinner specimen. Then note the uniformity of results between the two ovens in illustrating this drop.

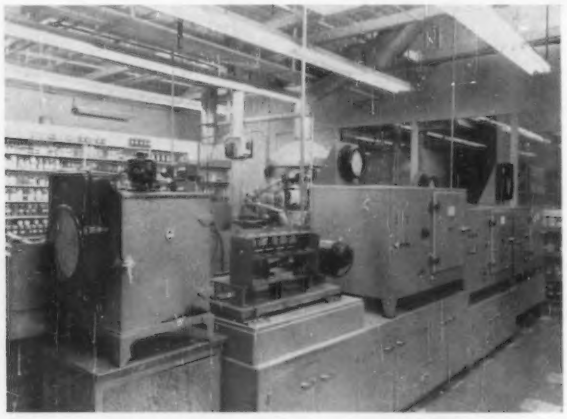


Fig. 13.—Ovens in the Apex Laboratory modified with tubular unit.

TABLE XX.—COMPARISON OF TUBULAR OVENS IN THE AGING OF EXTRUDED VINYL INSULATION FOR COMPOUND NO. 6, $\frac{1}{32}$ IN. INSULATION STRIPPED FROM NUMBER 22 SOLID COPPER CONDUCTOR, 7 DAYS, 121 C, 400 FPM.

Tube Number	2	7	10	Average
Oven Number 1				
Elongation retention, per cent	89	91	91	90
Tensile retention, per cent	105	105	101	104
Weight loss, per cent	10	10.4	9.5	10
Oven Number 2				
Elongation retention, per cent	89	87	86	87
Tensile retention, per cent	102	102	103	102
Weight loss, per cent	9.8	9.7	9.4	9.6
Oven Number 3				
Elongation retention, per cent	89	80	88	89
Tensile retention, per cent	105	105	103	104
Weight loss, per cent	10.1	11.7	11.1	11

TABLE XXI.—COMPARISON OF TUBULAR OVENS IN THE AGING OF EXTRUDED VINYL INSULATION UNDER MORE SEVERE AIR FLOW CONDITIONS FOR COMPOUND NO. 6, $\frac{1}{32}$ IN. INSULATION STRIPPED FROM NUMBER 22 SOLID COPPER CONDUCTOR, 7 DAYS, 121 C, 800 FPM.

Tube Number	2	7	10	Average
Oven Number 1				
Elongation retention, per cent	84	83	83	83
Tensile retention, per cent	106	110	108	108
Weight loss, per cent	12.1	11.7	12.1	12
Oven Number 2				
Elongation retention, per cent	83	83	83	83
Tensile retention, per cent	108	111	110	110
Weight loss, per cent	12.1	12.5	12.8	12.5
Oven Number 3				
Elongation retention, per cent	82	80	83	82
Tensile retention, per cent	108	108	108	108
Weight loss, per cent	13.9	13	13.1	13.3

Performance of the Tubular Oven in Heat Aging of Extruded Vinyl Insulation

Previous data have shown results of experiments conducted with dumb-bell specimens aged in the tubular oven. The following tables present data from tests on extruded insulation after removal of the conductor.

Small but consistent differences in results obtained during this test in oven No. 3 in comparison with the ones obtained in the other two ovens suggested more severe testing conditions. After a thorough investigation, it was found that the quantity of air flow in all tubes was correct and that all thermometers indicated 100 C. However, a recalibration of the three thermometers revealed that the one in oven No. 3 actually was in error by a $2\frac{1}{2}$ C lower reading. This means that the test (Table XVIII) was conducted in oven No. 3 at 102.5 C instead of 100 C. This condition was corrected.

Conclusions

Conclusions drawn from these tests

at higher temperatures accentuated our belief in the reproducibility of different tubular ovens, provided that all three testing conditions—time, temperature, and air flow, are equivalent. The test at 121 C was then repeated using a double rate of air flow.

The high degree of accuracy in duplication of results obtained in the three "tubular" ovens indicated that the basic objective of this project was satisfactorily met. Tests conducted according to a procedure, specifying temperature, time, and tubular air flows, are expected to produce a uniformity of results within one oven and reliable comparable values among different laboratories.

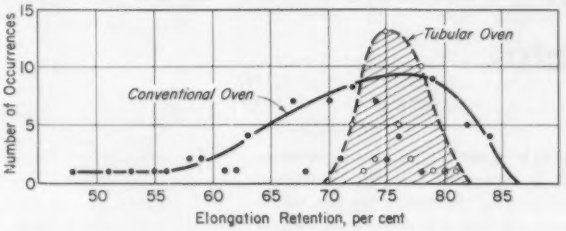


Fig. 14.—Comparative performance for the conventional and Apex tubular oven.

The ASTM Task Group of Committees D-11 and D-20 on Oven Aging of Plasticized Poly(Vinyl Chloride) and Highly Plasticized Elastomers has planned a round-robin program involving the Apex tubular oven, first, to obtain further information on performance of the unit in different companies, and secondly, to continue work toward the presentation of a reliable and reproducible test method for the heat aging of vinyl compounds.

REFERENCES

(1) H. K. Graves, "A Cell-Type Oven with Controlled Airflow for Testing Insulating Materials," *Insulation*, June, 1957.

(2) P. A. Raine, "An Aging Oven for PVC," *Distribution of Electricity*, Feb., 1947.

Discussion of Paper on Physical Changes In Setting Gypsum Plaster[1]

MR. C. G. SHUTTLEWORTH.[2]—Volume changes that occur during the hydration of gypsum plasters are of most importance in casting operations where models or molds of one kind or another are made. In these operations, the gypsum usually is mixed with water to produce a slurry of pourable consistency much like heavy cream: and, in order to prevent the hemihydrate gypsum particles from settling out, it is common practice to mix the slurry until the initial stiffening takes place before the slurry is poured. The stiffening action then prevents settling out, with the result that casts of uniform density can be made.

It would be interesting if Mr. O'Kelly could determine the per cent expansion by this method, to see if the result would be different from that obtained by the method described in the paper. It would seem that mixing to initial stiffening would prevent the initial shrinkage observed in the method described, where the mixture is not stirred until initial stiffening takes place. It has been our experience that more reproducible results are obtained when the plaster is stirred to the inital stiffening before pouring into the rubber-lined trough, where expansion is determined by a micrometer gage.

Also, it should be noted that the setting expansion of calcined gypsum can be altered over quite a range by the addition of various chemicals. Based on the author's statements that the reason for the increase in apparent volume on setting is that "needle-like crystals do not pack well" and that "the gypsum formed on hydration is in the form of needles," it must be that certain chemicals have the effect of changing the crystal shape so that the crystals formed are more cubical and less needle-like and therefore pack together better causing less increase in apparent volume. Since plasters which have subnormal setting expansion also have lower strength, the above hypothesis may be correct, since the interlocking of long, needle-like crystals would create a stronger crystalline structure than a similar structure of short, blocky crystals.

MR. B. M. O'KELLY (*author's closure*).—A slurry of hemihydrate and water, if undisturbed after the mixing process, will have developed, at initial set, a moderate degree of structure comprising hemihydrate particles and gypsum crystals in contact, the latter (as yet) poorly developed. The existence of such a structure necessarily precludes optimum packing of the solid and liquid present in the mass so that the apparent volume of the setting mass is greater than the combined absolute volumes of the solid and liquid phases present.

If the setting mass be continually stirred from the time of adding the hemihydrate to the water until the initial set, the development of any structure will be very largely prevented, so that the mass tends to remain fluid. In this case, the apparent volume of the setting mass will tend closely to the combined absolute volumes of the solid and liquid phases present, provided that prolonged mixing has not caused inclusion of air bubbles. Thus, mixing to the "initial set" should produce a larger percentage contraction than occurs in the undisturbed sample.

The degree of hydration at the "time of initial set" will be substantially the same in both the stirred and the unstirred samples. It seems probable, therefore, that stirring the sample to the initial set will have little or no effect on the expansion (measured from the low point) or on the ultimate strength. This latter belief is supported by the work of Rebinder, *et al.*,[3] who found no effect on subsequent strength development of continuous shearing up to the initial set. Their use of large amounts of inert filler in their plaster makes for caution in relying too heavily on their work.

It seems unlikely that the dilatomitic technique could be used to study the effect of mixing to the initial set, since the time available for filling the test apparatus would be excessively short.

[1] B. M. O'Kelly, "Physical Changes in Setting Gypsum Plaster," ASTM BULLETIN, No. 237, April, 1959, p. 55 (TP 75).

[2] Chief Chemist, Bestwall Gypsum Co., Paoli, Pa.

[3] V. N. Izmailova, E. E. Segalova, and P. A. Rebinder, "A Study of Structure Formation in Water Suspension of Calcium Sulphate," *Doklady Akademii Nauk S.S.S.R.*, Vol. 107 (3), pp. 425–427 (1956). National Research Council of Canada, *Technical Translation TT-672*.

A New Calibration Technique for Gas Transmission Measuring Apparatus

By T. McAVOY

Results from any piece of experimental equipment can be only as accurate as the calibration of the equipment. It is contended that the calibration method specified in the ASTM method of test for measuring the gas transmission rate of plastic sheeting[1] is not as accurate as it could be. A method is proposed for improving the accuracy.

IN THE analysis of a large series of unpublished tests conducted with four transmission test cells, it was noted that the average results for each of several different membranes varied from cell to cell by a constant amount. The cells were not geometrically identical but were constructed and operated in accordance with ASTM Method D 1434.[1] Specimens of the various membranes had been obtained in a manner that was most likely to assure uniformity, and all other known precautions were taken to provide consistent test conditions. The persistent difference in results between cells, therefore, could be attributed to either the theory of operation or the operating technique. These discrepancies are here attributed to the operating technique—specifically, the method of calibration.

Analysis of Calibration

The cell design is schematically represented in Fig. 1. During transmission tests with this apparatus, a large pressure difference is produced across the test membrane, and the change in pressure and volume of the calibrated volume on the low-pressure side are used to calculate the rate of gas transmission. Conversion of these experimentally observed changes in pressure and volume to a rate of transmission is achieved by the formula:

$$\frac{dn}{dt} = \frac{dh}{dt}\left[\frac{2ah - a(h_L + h_B) - V_f}{RT}\right] \quad (1)$$

where:

a = area of capillary $\overline{AB}$
R = universal gas constant
T = absolute temperature
n = quantity of gas transmitted in mols
t = time
V_f = void volume from B to D = V_{BC} plus V_{CD}
V_{CD} = void volume from C to D, and
V_{BC} = volume from B to C.
h, h_L, and h_B are as shown in. Fig. 1.

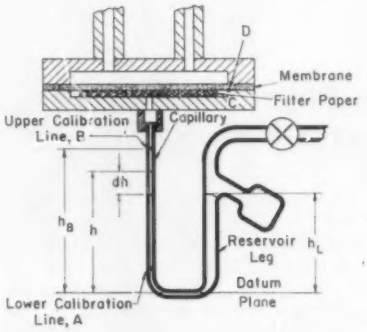


Fig. 1.—Schematic design of transmission cell.

Of the quantities used in the formula, h, T, and dh/dt are the observed experimental values; a is easily determined through the weight-volume relationship of the mercury necessary to fill the calibrated length of the capillary; h_L and h_B are linear measurements; and R is a natural constant. V_f is the sum of V_{BC} and V_{CD}, of which V_{BC} is also easily established by mercury displacement. V_{CD}, however, is given as either:

1. *In a flat-plate cell:* The void volume of the filter paper used to support the pressure difference across the membrane; or
2. *In a cell with a depression:* The volume of the depression minus the solid volume of the supporting filter paper.

In either case, but particularly for cells of high sensitivity, the value for V_{CD} constitutes a large portion of the total value of V_f. Since V_f is a major factor in the equation for the measured rate of transmission, its calibration must be accurate. In the standard method of calibration, however, the volume V_f can be assumed to be an accurate, unvarying quantity only if (1) the porous paper filter disk will sustain, without deflection, the compressive forces caused by the absolute pressure difference across the membrane, and (2) the paper disk exactly fits the depression in the depressed cell, or (3) the test membrane intimately conforms to the contour of the paper edges without the creation of any additional volume by wrinkling or bridging between the paper edge and the cell surface in the flat-plate type cell. These assumptions, necessary to the accuracy of the calibration, cannot pass unchallenged.

Proposed Modification of Calibration

To be valid, the volume V_{CD} must be measured under conditions of test—the calibration must simulate the actual test compressive loads on the filter paper support. To do so, the values a, h_L, and h_B are first determined in the standard manner; V_{BC} may be also so treated or considered with V_{CD} as part of the unknown volume V_f. After these preliminary measurements, the cell volume when not subject to change can be determined simply from the positions of the mercury levels in the capillary and reservoir legs caused by different gas pressures acting on the mercury surface in the reservoir leg. From this information the unknown volume can be computed in accordance with the perfect gas law. The very act

THOMAS McAVOY, a chemical engineer for the Hotpoint Div. of the General Electric Co., has specialized in the field of thermal insulation. Working to confine the high-molecular-weight gases that so greatly increase the efficiency of insulation, he found it necessary to explore the field of gas permeation through plastics. This study was prompted by the need for great accuracy in short term measurements because of the long time for which the insulation must perform.

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[1] ASTM Method of Test for Gas Transmission Rate of Plastic Sheeting (D 1434–58) 1958 Book of ASTM Standards, Part 9, p 460.

of changing the pressure under the membrane, though, does induce a change in the absolute pressure difference across the membrane and, consequently, will alter the value of the volume V_{CD}. If, however, the pressure change under the membrane is compensated by an equivalent change above it, there can be no change in the resultant forces compressing the filter paper and, as a consequence, there will be no tendency for the resiliency of the filter paper to effect a change in confined volume. With this parameter stabilized, it is now definitely possible to employ separate test pressures within the cell to compute the unknown portion of the total volume.

Development of Formulas

Using the symbols and schematic diagram of Fig. 1, a formula to determine the volume V_f was developed.

In the initial state, a quantity n of gas, of volume V_1, confined between the membrane and the mercury in the capillary tube at a pressure P_{C1} is expressed by:

$$n = \frac{P_{C1}V_1}{RT_1} \quad \ldots\ldots\ldots (2)$$

and the same quantity at a second pressure P_{c2}:

$$n = \frac{P_{C2}V_2}{RT_2} \quad \ldots\ldots\ldots (3)$$

With a membrane of low permeability in the cell, there would not be adequate time during the calibration for more than a negligible quantity of gas to permeate the membrane and, consequently, the quantity n can be assumed to be constant. Furthermore, with the relatively small changes in pressure being induced, the extensive surface area in the apparatus per unit gas volume, and the large heat capacity of the apparatus, T_1 can be assumed to equal T_2. Thus:

$$P_{C1}V_1 = P_{C2}V_2 \ldots\ldots\ldots (4)$$

Expressing the pressure of the gas in the capillary leg, P_C, in terms of the gas pressure in the reservoir leg, P_R, and V_1 and V_2 in terms of V_f:

$$P_{C1} = P_{R1} + h_{L1} - (h_1 + C) \ldots (5)$$

$$P_{C2} = P_{R2} + h_{L2} - (h_2 + C) \ldots (6)$$

$$V_1 = V_f + a(h_B - h_1) \ldots\ldots (7)$$

$$V_2 = V_f + a(h_B - h_2) \ldots\ldots (8)$$

where: C = correction for capillary suppression

Substituting and solving:

$$V_f = a \left[\frac{(h_B - h_2)\,[P_{R2} + h_{L2} - (h_2 + C)] - (h_B - h_1)[P_{R1} + hL_1 - (h_1 + C)]}{(P_{R1} - P_{R2}) + (h_{L1} - h_{L2}) - (h_1 - h_2)} \right] \quad (9)$$

Experimental Procedure and Results

To calibrate the cell volume according to the proposed theory, little additional equipment is required. Two gas burettes and two side-arm leveling bulbs with the necessary connecting tubing and manometric fluid were used to adjust the pressures above and below the membrane. Three-way stopcocks above the burettes permitted gas to be removed from or added to the system.

above the membrane, P_{T1}, by the following equation:

$$P_{T2} = P_{T1} + (P_{R2} - P_{R1}) - (h_{L1} - h_{L2}) - (h_2 - h_1) \ldots\ldots (13)$$

Adjustment of the pressure P_{T2} in accordance with Eq 13 will, by itself, alter the balance of the system and the values for computing the pressure; therefore, the experimenter will find that this operation must be achieved by successive approximations.

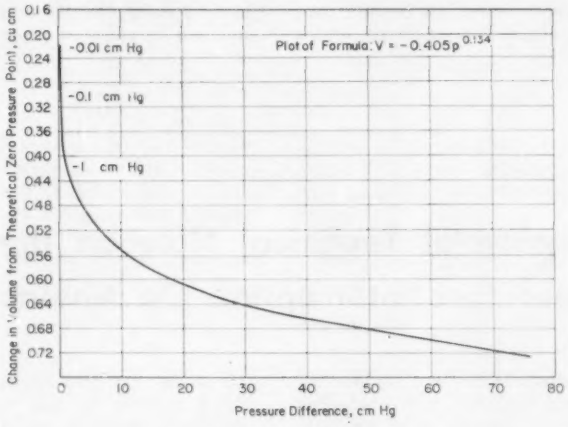


Fig. 2.—Cumulative change in volume from zero pressure point *versus* pressure difference across membrane.

Examination of a simplified version of the formulas for the calibration of the cell is important to reveal the most desirable experimental conditions under which the calibration should be conducted:

$$P_{C1}V_1 = P_{C2}V_2 \ldots\ldots\ldots (4)$$

$$P_{C1}V_1 = P_{C2}(V_1 + a\Delta h) \ldots (10)$$

$$\frac{P_{C1}}{P_{C2}} = \frac{V_1 + a\Delta h}{V_1} \ldots\ldots\ldots (11)$$

In the average apparatus, with Δh at its maximum value, the ratio $(V_1 + a\Delta h)/V_1$ will be approximately 1.08.

$$\frac{P_{C1}}{P_{C2}} = \frac{V_1 + a\Delta h}{V_1} \sim 1.08 \quad (12)$$

$$P_{C1} \sim 1.08\, P_{C2}$$

Since it is apparent that during calibration the total change in the gas pressure beneath the membrane will be limited to a value of approximately 8 per cent of the initial pressure, it is advisable to perform the calibration at other than the low pressures normally used during transmission tests. High operating pressure will create proportionately greater total changes in the observed readings, thereby permitting a reasonable degree of accuracy without excessive emphasis on the precision of the accessory calibration equipment.

To maintain constant the compressive force upon the membrane and supporting filter paper, the pressure above the membrane, P_T, must be modified in terms of the pressures used within the reservoir leg and the initial pressure

Proceeding as described, changes in the calibrated volume V_f of a test cell caused by absolute pressure differences across the test membrane were determined. The cell used was made of stainless steel with a circular recession 0.006 in. deep and 3.578 in. in diameter. A Whatman type No. 42 filter paper disk, approximately 0.009 in. thick and 3.54 in. in diameter was used as the support for the membrane, which was 2 mil, type 10, Saran film.

With absolute pressure differences across the membrane, p, ranging from 7.5 to 760 mm of mercury, the changes in volume caused by increments of pressure were determined. A graph on log-log paper of the volume change for a given pressure increment *versus* the average pressure difference across the membrane during that increment was found to be a straight line with the formula:

$$\text{Log}\,\frac{(V_1 - V_2)}{(p_1 - p_2)} = -0.866 \log \frac{(p_1 + p_2)}{2} - 1.265 \ldots\ldots (14)$$

Substituting and rearranging

$$\text{Log}\,\frac{\Delta V}{\Delta p} = -0.866 \log p_{avg} - 1.265 \quad (15)$$

$$\frac{\Delta V}{\Delta p} = 0.0542\, p_{avg}^{-0.866} \ldots\ldots (16)$$

$$\int_{v_1}^{v_2} dV = \int_{p_1}^{p_2} 0.0542\, p^{-0.866}\, dp \quad (17)$$

Change between any two pressures is then expressed as

$$V_1 - V_2 = 0.405\,(p_1^{0.134} - p_2^{0.134}). \quad (18)$$

Total change from the theoretical zero point is illustrated in Fig. 2.

Summary and Conclusions

It has been quite evident on the basis of past experimental work that the volume calibration of transmission cells of the type discussed has been in error by the amount of compression of the filter paper that resulted from the absolute pressure difference across the test membrane. Because of differences in the geometries of the cells used, this factor varied with the individual cells. Therefore, results from cells that were not identically constructed did not agree among themselves and were not accurate. The proposed calibration procedure uses compressive loads that simulate conditions during experimental transmission tests and uses the same laws for calibrating the apparatus that are used to calculate experimental results. Calibrating by this more basic standard should bring all apparatus into virtually exact agreement and improve the accuracy of the results. The experimenter should particularly remember that the cell must be calibrated for each pressure if more than one pressure difference is used in his studies. It may also be advisable to determine the effect of the stiffness of different membranes on the calibrated volume at different pressures, particularly if the stiffness of the specimens is high.

Discussion of Technical Note on the Effect of Temperature Interruption On Anelastic Creep[1]

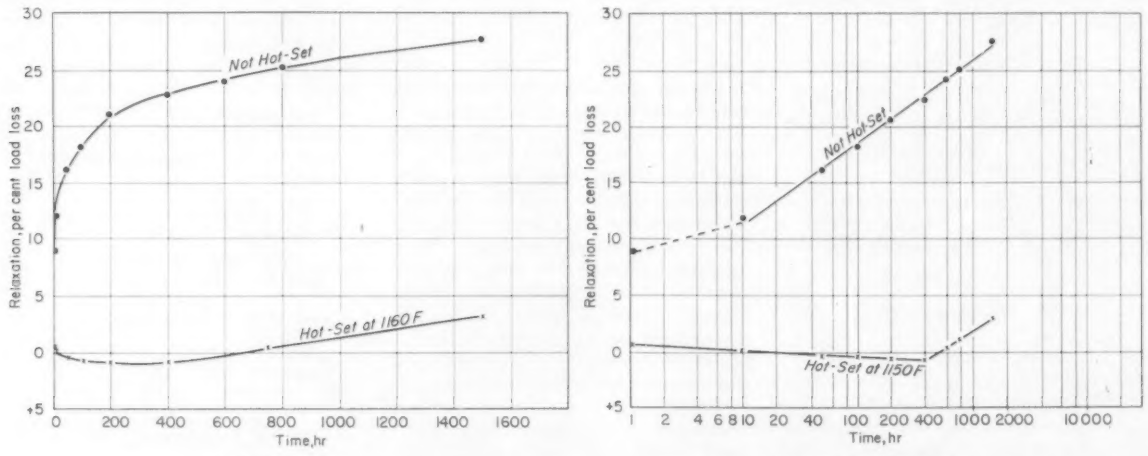
MR. RONALD D. CROOKS[2] (*by letter*).—Mr. Lubahn's remarks and conclusions regarding the freezing in of anelastic strains to resist plastic flow are interesting. However, in the spring industry we have found these effects to be temporary. In springs, the process of freezing in anelastic strains is known as hot setting, and has long been used to reduce stress relaxation and promote stable behavior of springs for elevated temperature service. Experiments have shown that the amount of resistance to stress relaxation built into a spring is controlled by the time, temperature, and stress employed during the hot-setting process. It has further been observed in long-time stress relaxation tests on hot-set springs that the period of anelastic recovery that overcomes stress relaxation is temporary. (See Fig. 1.) The rate of plastic flow occurring during the stress relaxation test inevitably exceeds the decreasing rate of recovery, after some time, and plastic flow proceeds at a rate equivalent to that found for springs which have not been hot-set. Moreover, the effects of anelastic recovery seem to run out rather suddenly, as shown in the plot in Fig. 1 (*b*).

Data from springs in which the primary applied stress is shear, and in which complex residual stress patterns may exist, are not directly comparable to tensile creep data. However, it is believed that the same phenomena are involved, with the possible exception of the effect of the relief of residual stresses. The point is that the period of stability or lack of apparent plastic flow obtained by hot setting is temporary, and, therefore, the extrapolation of such data is extremely risky. Any commercial application of this process must be entered into with the full knowledge that the inevitable plastic flow can only be delayed, not stopped.

Our experiments also have confirmed Lubahn's findings that total time at temperature is the pertinent parameter and that temperature interruption does not basically alter the response.

[1] J. D. Lubahn, "The Effect of Temperature Interruption on Anelastic Creep," ASTM BULLETIN No. 239, July, 1959, p. 61 (TP 141).

[2] Metallurgist, Associated Spring Corp., Bristol, Conn.



(*a*) Linear plot

(*b*) Semilogarithmic plot.

Fig. 1.—Stress relaxation test data; helical compression springs; Inconel X alloy; No. 1 temper; aged 1350 F, 16 hr; test temperature 1000 F; test stress 40,000 psi, corrected.

The Langley as a Unit for Timing Outdoor Exposures*

By C. R. CARYL

THE langley is the unit most widely used in pyrheliometry, the measurement of the amount and intensity of solar radiation. It was proposed in 1947 and named for Samuel P. Langley, a pioneer in the field of radiation measurement. One langley is equal to 1 g cal of radiant energy per sq cm of exposed area, or 3.69 Btu's per sq ft.

The U. S. Weather Bureau measures solar radiation in langleys at about a hundred of its own and cooperating stations, and every month publishes the data for each locality (1).[1]

The Eppley pyrheliometer is the instrument used by the Weather Bureau and by most outdoor testing stations to measure solar radiation, while a strip-chart potentiometer draws a daily graph of the data. Both the pyrheliometer and several kinds of recorders have been thoroughly described in the literature.

TABLE I.—TYPICAL AMOUNTS OF SOLAR RADIATION (IN LANGLEYS) RECORDED IN PHOENIX, ARIZ.

On a Horizontal Plane, (U S Weather Bureau)		At 45 deg South, Direct (2), Annual Total	On an Equatorial Mount (2), Annual Total
Year	Daily Average		
1958....	..	193 382	262 864
1957....	498	182 048	248 265
1956....	532	199 402	....
1955....	557	192 734	....
1954....	542	....	....

The variation in the solar radiation from year to year (Table I) is sometimes as great as the total radiation for a whole month. Thus the solar radiation in one year often equals that in the next 13 months. So even a year as a unit for timing exposures is rather variable, and, of course, for shorter units of time, the variations in the amount of radiation are greater.

A cloudy day may produce fewer than 100 langleys, whereas the total for a cloudless day will exceed 600 langleys; the total for an hour may vary from 1 to 100 langleys.

The three charts in Figs. 1 and 2 are in effect "langley pictures" of the weather on two days in Phoenix, Ariz.

The two graphs for December 19 (Fig. 1) are recordings of solar radiation on an equatorial mount and on a stationary rack at 45 deg south during a sunny day in Phoenix. Ordinates show intensity of radiation, abscissas the time. Sunrise (at the lower right) was just after 7 a.m. (solar time) and sunset just before 5 p.m. Total radiation in langleys may be read directly from the graph for any 20-min period; intensity in langleys per minute by dividing the ordinates by 20.

At solar noon, intensity of radiation was 1.3 langleys per min on the equatorial mount and 1.2 at 45 deg south. On two days each year, Feb. 18 and Nov. 23, when the sun at solar noon is just 45 deg above the horizon, it shines at normal incidence on a rack facing south at 45 deg; hence the intensity at noon on those days is the same on the 45-deg south mount as on the equatorial mount. On Dec. 19, the latter received 586 langleys and the former 476.

The third chart (Fig. 2) is for one of the longest days of the year, June 15, mostly cloudy, with over 14 hr between sunrise and sunset and a total of 381 langleys. The sun broke through the clouds at 10:30 a.m. and shone brightly until 12:10 p.m. with one slight interruption.

Specimens of colors and plastics being exposed that day would fade and degrade only slightly, if at all, before 10:30 a.m. At that time, when solar radiation intensity rose above 0.823 langley per min, the rate of fading and degradation increased greatly, and a clock attached to the recorder began ticking off the minutes to count the popular "sun hours" (see below). However, when the intensity dropped at 12:10 p.m. and the clock stopped, it is fallacious to assume that photochemical or photoactivated reactions stopped just as abruptly, and began again with the clock at 12:20 p.m., when intensity again rose above the 0.823 level.

While the langley is satisfactory for measuring solar radiation, the ideal unit for timing exposure periods should also correlate the effects of every other component of weather, including temperature, moisture, wind, and airborne contaminants. These components of weather have been thoroughly discussed in a symposium on conditioning and weathering (3); their effects on adhesives and plastics are discussed in another symposium (4). It seems to be generally agreed that light, or solar radiation, is the greatest single cause of weathering of most materials.

The ideal unit for integrating the several components of weather may be found at some future time. For the present, we have only the langley, calendar units of time such as days or months or years, and the "sun hour" or ultra-

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* Presented at a meeting of Committee D-11 on Rubber and Rubber-Like-Materials Pittsburgh, Pa., Feb. 6, 1959.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

COLEMAN R. CARYL has been director and sole owner of Desert Sunshine Exposure Tests, Phoenix, Ariz., since 1948, and has been studying the measurement of solar radiation, particularly its ultraviclet content, and its effects on paints, plastics, and colors. Prior to 1948, he spent 25 years in the chemical industry. His B.S. and M.S. degrees in organic chemistry were received from Kalamazoo College and Yale University, respectively.

violet sun hour. This last unit has been widely used for many years. It is an hour during which the intensity of solar radiation is more than 0.823 g cal per sq cm per min (0.823 langley per min).

It should be mentioned here that the accuracy of the Eppley pyrheliometer is said by its maker (11) to be $\pm 1\frac{1}{2}$ per cent, therefore radiation measurements taken with that instrument should be rounded off to the nearest tenth of a langley.

The work of the Committee on Colorfastness to Light of the American Association of Textile Chemists and Colorists has proved the sun hour unreliable for use in fading tests, because it is false to assume that little or no actinic degradation occurs below the radiation intensity level of 0.823 langley per min.

After an investigation of the outdoor weathering of colored vinyl films in Bound Brook, N. J., and in Miami, Fla., Clark (5) concluded that: "In

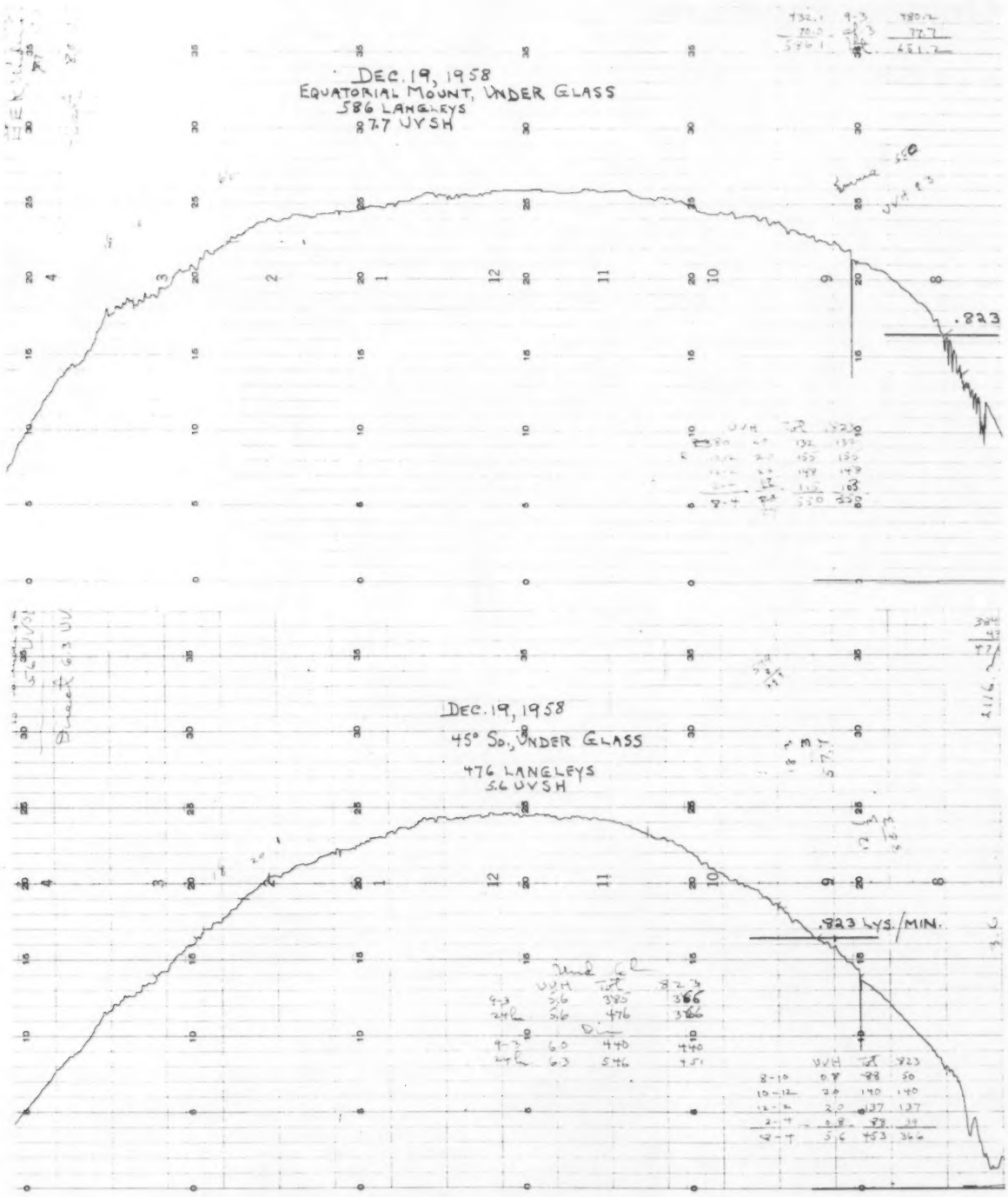

Fig. 1.—Record of solar radiation on a sunny day in Phoenix.

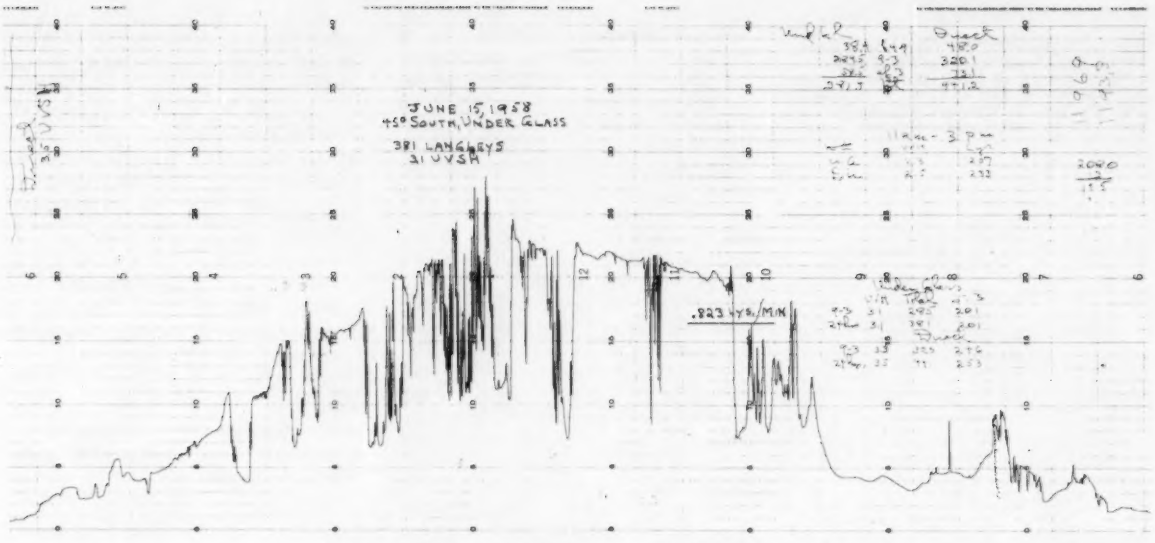

Fig. 2.—Record of solar radiation on a cloudy day in Phoenix.

Bound Brook, N. J., specimens exposed during the winter season required, on the average, 280 sun hours to achieve the same results occurring in 100 sun hours in the summer months, while in Miami, Fla., the difference between summer and winter tests was much less, showing 160 sun hours in winter equal to 100 in summer. The sun hour measurement alone cannot be used for consistent results throughout the year."

Because the total radiation received during a sun hour is capable of wide variation, and since the amount of solar radiation varies considerably from month-to-month or year-to-year, there remains only the langley as the one unit that is an accurate measure of the most important factor of the weather—solar radiation. An examination of the advantages and disadvantages of this unit of measure would therefore seem to be in order.

In a year-long series of tests in Phoenix, Millson (6) exposed 36 identical cards, divided into 3 sets of 12 cards each. Three cards (one from each set) were exposed each month. Each card held seven automotive fabrics and four of the Blue Standards of the AATCC.

Each month, a card from set No. 1 was exposed continuously for 30 days[2] under glass, at 45 deg south. A card from set No. 2 was exposed in the same cabinet for the same 30 days, but only from 9 a.m. to 3 p.m. each day. A card from set No. 3 was also exposed in the same cabinet but only from 3 p.m. to 9 a.m.

Cards from sets No. 2 and 3 were kept in a dry, cool room when not being exposed in the cabinet. All three cards were returned to Bound Brook at the end of each exposure period, with a record of the amount of radiation received, in langleys, the temperature, humidity, etc., during each of the three exposure periods.

On the first day of each month another three cards were started. Thus at all times during the year there were always two cards on exposure and one inside. The number of langleys of radiation received in 24 hr by a card from set No. 1 was therefore equal to the combined total received by the cards from sets No. 2 and 3. So, if the combined amount of fading of the specimens on the cards from sets No. 2 and 3 were equal to the fading on set No. 1, then fading would be in proportion to the number of langleys received.

To determine the amount of fade, duplicates of the fabrics on the 3 sets of cards were exposed in the Fade-Ometer for periods of from 10 to 400 hr, in 10-hr increments, to permit a direct comparison between sunlight and Fade-Ometer fading on a numerical basis. The numbers entered in Table II, then, may be taken to be proportional to the amount of fade in the specimens in the sunlight-exposed cards.

In six months of the year, the combined total fade of specimens No. 3 and 2, which were exposed to the same number of langleys as specimen No. 1, exactly equalled the fade of specimen No. 1, while in five other months the figures were very close. Thus the fading of Blue Standard L 4 was practically in proportion to the number of langleys of radiation received, irrespective of the time of day or the season of the year.

To summarize all of Millson's exposures of this series in Phoenix, the Fade-Ometer hours for each of the eleven samples on each of the three sets of cards exposed during the year (three cards per month) were added. The total Fade-Ometer hours, and thus the fading of each sample, was found to be in the proportion of 40 for set No. 1 to 27 for set No. 2 to 14 for set No. 3, as shown in Table III. The ratio of langleys of radiation received by each set of cards was 40 to 25 to 14 for sets No. 1, 2, and 3, respectively. This is excellent evidence that fading, at least of these eleven colors, is practically in direct proportion to the langleys of radiation received, irrespective of the time of day or the season of the year. However, the lower-intensity radiation of the

TABLE II.—THE NUMBER OF HOURS IN THE FADE-OMETER REQUIRED TO EQUAL THE FADE OF THE L 4 BLUE STANDARD ON THE CARDS EXPOSED IN PHOENIX.

Card Group	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Set No. 3 (Exposed 3 p.m. to 9 a.m.) . . .	30	60	70	80	70	70	110	100	50	80	50	40
Set No. 2 (Exposed 9 a.m. to 3 p.m.) . . .	90	120	120	130	130	130	170	150	110	140	110	80
Total—Sets Nos. 3 and 2	120	180	190	210	200	200	280	250	160	220	160	120
Set No. 1 (Exposed 24 hr)	160	180	180	210	200	200	250	250	170	230	160	130

[2] February card was also exposed on March 1 and 2.

TABLE III.

The Ratio Between the Total Fade-Ometer Hours (and Thus the Total Fade) of Eleven Colors Exposed at Three Different Periods Each Month of 1955 in Phoenix, Compared with the Ratio of Langleys of Radiation Received by Similar, Sunlight-Exposed Colors.

Fade-Ometer Specimen No.	Set No. 1 (24 hr Exposure	Set No. 2 (9 a.m. to 3 p.m. Exposure)	Set No. 3 (3 p.m. to 9 a.m. Exposure)
L4	40	25	14
L5	40	25	14
L6	40	27	17
L7	40	26	20
Green 1	40	28	11
Green 2	40	27	12
Green 3	40	28	13
Blue 4	40	26	12
Blue 5	40	28	13
Gray 6	40	28	13
Tan 7	40	29	12
Average all Fade-Ometer specimens	40	27	14
Sunlight-specimens[a]	40	25	14

[a] Proportional langleys of radiation received, sunlight-exposed specimens.

This close agreement between the fading of colors and the total langleys of radiation received has been confirmed by the author (2), in comparisons of exposures of colors at 45 deg south, on an equatorial mount, and on an equatorial mount having ten aluminum mirrors which produce an intensity of radiation about ten times greater than at 45 deg south. Certain colors which fade in 7200 langleys (about 80 hr) at 45 deg south will fade in 7200 langleys (about 10 hr) on the mirrored equatorial mount (at the same temperatures), again confirming that fading increases nonlinearly with intensity of radiation.

While Millson's tests were in progress, the author (2) exposed a number of the AATCC Blue Standards to a definite number of langleys of radiation from 9 a.m. to 3 p.m. Identical sets were exposed from 3 p.m. to 9 a.m. and for 24 hr per day, to the same amount of radiation. All sets faded practically the same. Longer tests on other Blue Standards gave similar results.

The author also exposed three of the AATCC Blue Standards by the Sunlight (9 a.m. to 3 p.m.) and by the Daylight (24 hr per day) methods and found that, in general, fading was proportional to the amount of radiation received. The object of this test was to determine the seasonal variations in the fading of three of the new Blue Standards. However, much of the data on fading was in close agreement with Millson's findings.

Ninety-six identical sets of L6, L7, and L8 specimens were prepared. Eight sets were exposed for 30 days[2] during each month of 1957, four at 45 deg south, and four on an equatorial mount for the exposure periods shown in the following listing:

Exposure	Period of Exposure
45 deg south, under glass	9 a.m. to 3 p.m. (Sunlight)
45 deg south, under glass	24 hr (Daylight)
45 deg south, direct	9 a.m. to 3 p.m. (Sunlight)
45 deg south, direct	24 hr (Daylight)
Equatorial mount, under glass	9 a.m. to 3 p.m. (Sunlight)
Equatorial mount, under glass	24 hr (Daylight)
Equatorial mount, direct	9 a.m. to 3 p.m. (Sunlight)
Equatorial mount, direct	24 hr (Daylight)

At the end of each 30 days, the fade of each sample was rated visually by two experienced observers (three during January and February) using the ISO gray scale. These values were then converted to the color difference units used by Norton (7), and are shown in Tables IV and V. The ratio of Daylight-to-Sunlight fading was about the same as the ratio of Daylight-to-Sunlight radiation exposure.

Various sets of colors were also compared for fading, in which all conditions were the same except for the number of langleys of radiation. For example, L6 exposed under glass from 9 a.m. to 3 p.m. was compared with L6 exposed under glass for 24 hr, and in the 12 months, nine of the pairs of colors faded in proportion to the radiation received. In all of the 45 deg south exposures 48 of the 72 pairs so faded, and on the equa-

TABLE IV.—COMPARISON OF COLOR DIFFERENCE WITH RADIATION RECEIVED, 45 DEG SOUTH UNDER GLASS.

Exposure	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	Total Color Difference Units											
Sunlight (9 a.m. to 3 p.m.)	9.3	11.1	12.1	11.1	8.4	9.2	17.6	11.1	11.1	6.5	12.1	12.1
Daylight (24 hr)	8.2	14.9	14.1	13.9	13.2	13.1	13.8	11.2	11.2	13.0	12.1	12.1
Ratio, Daylight/Sunlight	0.9	1.3	1.2	1.3	1.5	1.3	0.8	1.0	1.0	2.0	1.0	1.0
	Total Radiation, thousands of langleys											
Sunlight (9 a.m. to 3 p.m.)	7.7	8.6	11.4	10.8	10.3	9.8	9.4	10.1	11.5	9.9	10.5	9.8
Daylight (24 hr)	9.3	11.1	15.1	14.6	13.9	13.1	12.7	13.4	15.2	12.7	12.9	11.8
Ratio, Daylight/Sunlight	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2

TABLE V.—COMPARISON OF COLOR DIFFERENCE WITH RADIATION RECEIVED, EQUATORIAL MOUNT.

Exposure	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	Total Color Difference Units											
Sunlight (9 a.m. to 3 p.m.)	9.3	11.1	14.1	14.9	13.0	9.2	13.9	10.2	8.3	6.4	8.3	5.6
Daylight (24 hr)	11.1	13.1	15.8	15.7	17.0	19.0	17.9	17.8	18.6	13.0	12.2	7.5
Ratio, Daylight/Sunlight	1.2	1.2	1.1	1.1	1.3	2.0	1.3	1.7	2.2	2.0	1.4	1.3
	Total Radiation, thousands of langleys											
Sunlight (9 a.m. to 3 p.m.)	8.4	9.4	12.7	12.6	12.9	12.9	12.2	11.8	13.1	10.8	11.6	10.8
Daylight (24 hr)	10.9	13.5	20.2	22.0	23.2	24.6	22.1	19.6	22.2	16.1	16.1	14.4
Ratio, Daylight/Sunlight	1.3	1.4	1.5	1.7	1.8	1.9	1.8	1.7	1.7	1.5	1.4	1.3

3 p.m. to 9 a.m. series caused slightly more fading, proportionately, than the radiation of the 9 a.m. to 3 p.m. series; so the conclusion is obvious that fading increases nonlinearly with increasing intensity of solar radiation.

It is interesting to note that the intensity of radiation before 9 a.m. and after 3 p.m. is mostly below the 0.823 langley per min level and would therefore be disregarded in using the sun hour, yet this radiation is one-eighth of the total and causes about one-seventh of the fading, a fact later confirmed by Norton (7).

torial mount, 50 of the 72 pairs. These results do not correlate as well as Millson's, probably because his method of evaluating fade was more accurate than the visual examination.

In a series of dyeings exposed in Phoenix and in Miami for an equal amount of radiation in both the Daylight (24 hr) and the Sunlight (9 a.m. to 3 p.m.) tests, Schmitt (9) found excellent duplication of results on most of the colors. He reported:

> Out of 63 swatches on all types of textile fabrics and different classes of dyes, we noted that the majority showed excellent similarity of fading when tested by the langley method in both the Daylight and Sunlight method.
>
> The data in the Committee's hands clearly indicate that Point No. 2 above is based on a totally false assumption, that is, significant fading does not occur below 0.823 g cal per sq cm. This point alone explains why the procedure in question (the use of the sun hour) has led to erratic results, incorrect judging of colorfastness, misconceptions as to the severity of fading in Florida as compared with other localities in the United States, and misconceptions as to the relationships between sun fastness and Fade-Ometer fastness on specific specimens. Results indicated that fading occurs at all levels, increasing nonlinearly with intensity.

A year later, the same committee had completed many more tests on fading, from which Norton (7) concluded:

> The sun-hour method or any natural light method in which exposures are calculated or expressed on the basis of time only cannot be a valid, reproducible, and repeatable test method.
>
> In natural light exposures, the greatest contributing factor in the amount of color change produced is the total amount of radiation received. Langley units which integrate time and intensity of radiation as g cal per sq cm per min appear to be a satisfactory measure of total radiation received. Therefore, the langley unit appears to provide a satisfactory control for evaluating lightfastness properties.

On the recommendations of Norton's Committee, the new Daylight Test was adopted and appeared in the 1957 Year Book of the AATCC as Tentative Test Method 16C–1957. The same committee found that one standard fading hour in the Fade-Ometer produces a degree of fade comparable to an outdoor exposure of about 108 langleys.

In his investigations of the degradation of plastics, Woodland (8) has shown the difficulty of finding an exposure unit satisfactory for all materials. Polyethylene was shown to be susceptible to both thermal and photoactivated oxidation, and to absorb ultraviolet in the carbonyl band (2800 Å). Poly(vinyl chloride) also is degraded by heat, which causes discoloration and a very slow loss of mechanical properties, and by light, which causes embrittlement and loss of tensile strength. Polystyrene cannot be stabilized for long-term outdoor exposures and discolors only when exposed to radiation in the 2800 Å range. An ideal exposure unit for these three classes of plastics might be the langley, plus a factor for temperature, plus data from an instrument sensitive to shortwave radiation in the 2800 Å band.

The Committee on Exposure Test Methods of the Society of the Plastics Industry (10) exposed hundreds of vinyl films, in outdoor tests in six locations, both under glass and direct to the weather, and where possible, radiation exposure was recorded in langleys. One of the conclusions found the "measurement of exposure by total radiation (langleys) definitely superior to measurement by days."

Since that time (1953), the use of the langley for timing exposure tests has become commonplace, at least in Arizona. In concluding that the langley is at present the most satisfactory unit for timing outdoor exposure periods, it is hoped that nothing in this discussion will convey the impression that the author has an interest in using one unit in preference to any other. He is timing exposures now in hours, days, and years, in langleys, and in sun hours, and will welcome any new unit that the ingenuity of man can devise.

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Control Testing for Separation of Lightweight Material from Aggregate*

By E. C. HIGGINSON and G. B. WALLACE

A method of test, developed in the United States Bureau of Reclamation Laboratories, for evaluating the effectiveness of large-scale separation of lightweight material from aggregate is described. Field experience using this method of test at Glen Canyon Dam is reported. The effects of the following factors on the accuracy, speed, and safety of the test are evaluated: methods of removing lightweight materials, moisture content of aggregate, rate of absorption of heavy liquid by the aggregate, and methods of washing heavy liquids from aggregate.

CONCRETE aggregate deposits used for Glen Canyon and Flaming Gorge Dams, now under construction by the Bureau of Reclamation, contain some lightweight particles which, if used in concrete subjected to freezing and thawing, would pop out and scale away from the mortar, contributing to the deterioration of the concrete. To improve the quality of the concrete, the objectionable lightweight particles in the size range from No. 8 to 1½ in. are being removed by the heavy media separation process (HMS). In this process raw aggregates are fed into a vessel containing a water slurry of ferrosilicon and magnetite, as shown in Fig. 1. The medium is dense enough to float the objectionable lightweight particles which are then transported over discharge weirs and wasted. The usable heavyweight particles sink in the medium to the bottom of the vessel from which they are recovered for use in concrete.

Even when the operation of the HMS plant is uniformly controlled, some lightweight aggregate will be entrapped by heavyweight pieces and carried to the sink stockpiles. If the specific gravity of the medium drops, flow of the medium through the vessel is not uniformly controlled, quality of feed is lowered, or quantity of feed is increased, the quality of the sink product will be lowered. To control the heavy media process and to determine whether or not the product will meet the specifications requirements, it is essential to have a quick and accurate test. Such a test, referred to hereafter as the heavy-liquid test, is described below. This test is a modification of the procedures set forth in ASTM Method C 123 – 57 T.[1]

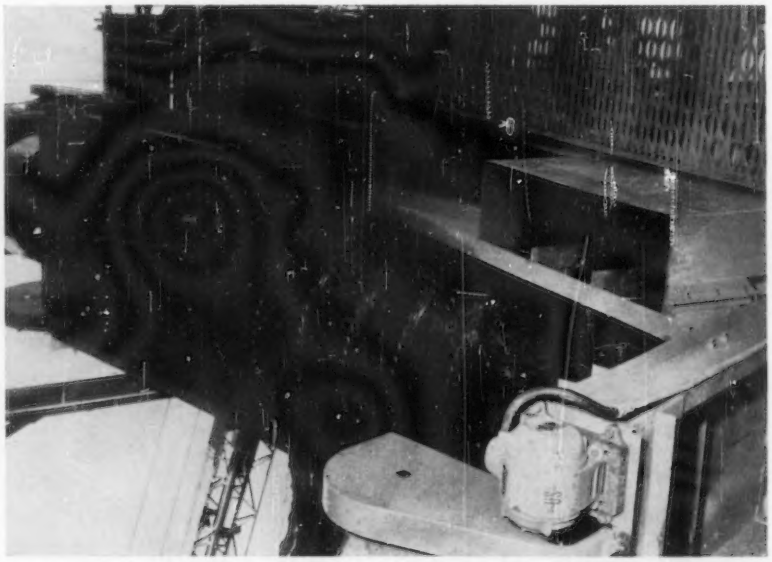

Fig. 1.—Spiral separator—heavyweights sink and are removed by spiral. Lightweights float over weirs in right foreground.

The Heavy Liquid Test

Essentially, the heavy-liquid test consists of placing a sample of aggregate from the HMS plant into a liquid of suitable specific gravity and removing and weighing the lightweight material

NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

* Presented at the Sixty-Second Annual Meeting of the Society, June 21–26, 1959.

[1] ASTM Method of Test for Lightweight Pieces in Aggregate (Tentative), 1958 Book of ASTM Standards, Part 4, p. 506.

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For the past several years, Mr. Wallace has actively engaged in laboratory research of water-reducing, set-retarding agents, as well as separation of lightweight material from aggregate by the heavy media process. He is responsible for tests of admixtures proposed for use on Bureau of Reclamation projects, and directs contemporary research in these materials.

which floats to the surface. Figure 2 shows results of the heavy-liquid test developed from this study and applied at Glen Canyon Dam during production of treated No. 8 to No. 4 sand from Sept. 10, 1958 to Nov. 10, 1958. The specifications require that not more than 2 per cent of the processed aggregate may have a specific gravity less than 2.50. Note from Fig. 2 that each time this amount was exceeded, it was possible to change the operating conditions and quickly reduce the amount of lightweight material, often to less than 1 per cent of the total product. Frequent control tests can practically eliminate wasting any appreciable amount of processed material for failure to meet the specification requirements as shown by the results of tests from Oct. 23 to Nov. 10, 1958.

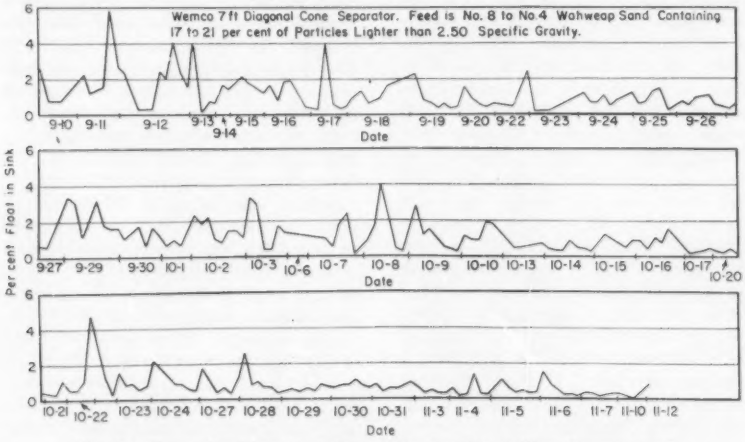

Fig. 2.—Heavy liquid test results on No. 8 to No. 4 Glen Canyon sand. Specifications prohibit over 2 per cent of HMS product to be lighter than 2.50 specific gravity. Feed contained about 20 per cent lightweights.

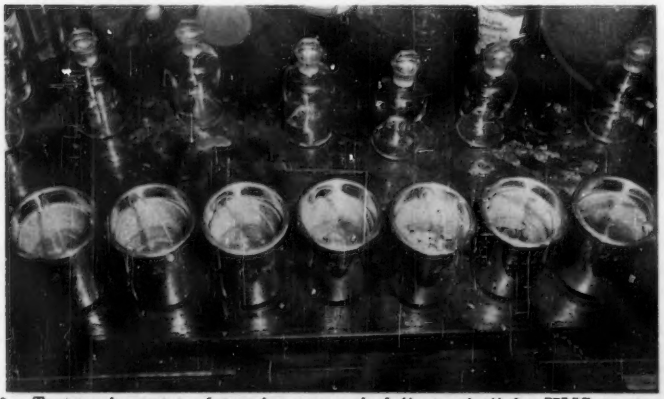

Fig. 3.—Test equipment to determine economical "cut point" for HMS treatment of aggregates.

Although the quality of the product may be satisfactory, the efficiency of a heavy media plant may be low if large quantities of heavyweight materials are being carried over the float weirs with the lightweight particles and being wasted. Increasing medium density, decreasing the feed, increasing retention time in the medium, increasing the specific gravity differential between top and bottom of medium pool will improve the sink product, but unless these factors are coordinated, optimum efficiency will not be obtained. By performing occasional heavy-liquid tests on the float or feed product, the amount of heavyweight material being wasted can be determined and, if necessary, changes made in the operating conditions to improve the plant efficiency.

The heavy-liquid test is also useful in evaluating the economics of separating an aggregate at various specific gravities, referred to as "cut points." Figure 3 shows the required test equipment being used to determine the cut point for Flaming Gorge Dam aggregates. The raw aggregate was first placed in the 2.60 specific gravity solution and the float removed, rinsed, and transferred to the next lower gravity solution, namely, 2.55. This procedure continued, finally terminating at the 2.30 gravity solution. All sink material and the final float material were rinsed and brought to a surface-dry condition and weighed. Results of the tests are shown in Fig. 4. Concrete durability requirements for Flaming Gorge Dam can be satisfied by separating the lightweights at a specific gravity of 2.50. The figure shows that this can be accomplished without producing a prohibitive amount of waste. About 20 per cent of the raw aggregate has a specific gravity less than 2.50. Note that at higher specific gravities the amount of float material increases rapidly. If a specific gravity

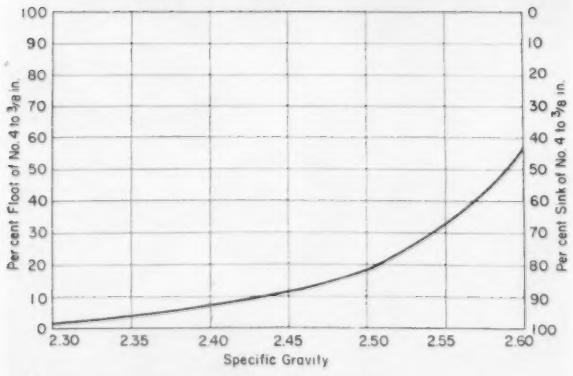

Fig. 4.—Sink-float specific gravity relationship. About 20 per cent of feed has a specific gravity less than 2.50. Waste increases rapidly at higher specific gravities

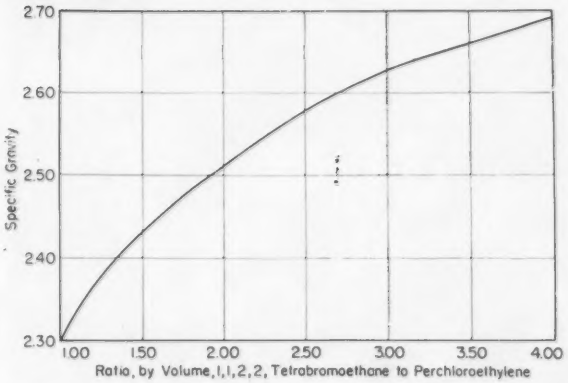

Fig. 5.—Approximate proportions (by volume) of 1,1,2,2,-tetrabromoethane and perchloroethylene for heavy liquids at various specific gravities.

of 2.60 was required for durability, over 55 per cent of the deposit would have to be wasted.

In developing the heavy-liquid test procedure, the effects of the following factors on the accuracy, speed, and safety of the test were evaluated: composition of heavy liquid, skimming *versus* decanting methods of removing lightweights from heavy liquid, moisture content of aggregate sample, rate of absorption of heavy liquid by the aggregate, and methods of washing heavy liquid from aggregate before weighing.

Composition of Heavy Liquid:

By combining various amounts of 1,1,2,2,-tetrabromoethane, which has a specific gravity of about 2.97, and perchloroethylene, which has a specific gravity of about 1.63, a heavy solution of any specific gravity normally required for separating aggregate can be prepared. Figure 5 shows approximate proportions by volume of these chemicals to make heavy liquids having various specific gravities.

Perchloroethylene was substituted in place of any of the lighter liquids permitted under ASTM Method C 123 – 57 T,[1] principally because it is somewhat safer. It is less volatile than carbon tetrachloride and benzene and will not flash as does monobromo-benzene or benzene. However, all of the chemicals cited above are highly toxic, both by absorption through the skin and by inhalation. They should be used only in a well-ventilated area, preferably under a forced draft hood, and care taken to avoid contact of the liquids with the skin or inhalation of the fumes. Use of protective clothing such as rubber gloves, rubber aprons, and goggles is advised. Perchloroethylene is more volatile than 1,1,2,2,tetrabromoethane, and the differential rate of evaporation will in a brief period of time cause a change in the specific gravity of the liquid mixture; hence, checking and adjustment of the specific gravity of the mixture are necessary before each test.

Preparation of Samples

To study the variables affecting the heavy-liquid test, samples were obtained from both sink and float products of a small laboratory HMS plant. Thus, the influence of the variables could be evaluated on samples containing a nominal percentage of lightweight material and on samples containing a high percentage of lightweight material. Preliminary tests indicated that the smaller sizes of aggregate are more difficult to process efficiently through HMS plants and that they are also more sensitive to variations in heavy-liquid testing procedures than the coarser sizes of aggregate. Therefore, the majority of tests described below were made using No. 8 to No. 4 sand-size aggregate. However, the final test procedure was evaluated on each standard-size aggregate shown below, together with the approximate weight of each sample:

Size	Weight (approximately, g)
No. 8 to No. 4	1000
No. 4 to ⅜ in.	5000
⅜ to ¾ in.	5000
¾ to 1½ in.	5000

Even though materials were blended, it was difficult to obtain identical samples. Therefore, to study the influence of a given variable, it was usually necessary to repeat the test on three companion samples. Before testing, each sample was rescreened and washed to remove oversize, undersize, and slime.

Removing Lightweight Material from Heavy Liquid

Two methods of removing the lightweight particles floating on heavy-liquid surfaces were investigated. In the method shown in Fig. 6, a saucer-shaped skimmer of No. 10 sieve cloth is used. The sample to be tested is placed in the heavy-liquid and vigorously stirred for 5 sec to free the lightweight particles surrounded and entrapped by heavyweight particles. About 15 sec are allowed for the turbulence to subside before the floating particles are removed by skimming. Care should be taken while skimming to avoid creating strong currents in the liquid which would disturb the settled material. Skimming depth should be just sufficient to remove aggregate particles floating on the heavy-liquid surface. Particles floating at a depth greater than ⅛ in. below the surface, called teeter particles, should not be removed with the float portion. After skimming, the excess heavy liquid is drained back into the beaker and the lightweight material transferred into the adjacent wire basket and beaker. The stirring and skimming sequence is repeated until all lightweight material has been removed. It is then washed in perchloroethylene and alcohol to remove the heavy liquid remaining on the surface.

The second method of removing floating particles from the heavy liquid utilizes the decanting procedure shown in Fig. 7. The sample is immersed in heavy liquid and stirred vigorously, then the induced turbulence is allowed to subside as in the skimming method. The upper portion of the heavy liquid containing the lightweight particles is then poured through a No. 10 screen into another beaker as shown. The

Fig. 6.—Skimming lightweights from heavy liquid surface, washing in perchloroethylene and alcohol.

Fig. 7.—Decanting lightweights from heavy liquid, washing in perchloroethylene and alcohol.

lightweight material retained on the screen is drained and washed as in the skimming method. The heavy liquid poured off is returned to the beaker containing the remainder of the sample, which is again agitated to release entrapped lightweight particles, and the decanting procedure repeated until all lightweight material is removed from the sample.

Eighteen tests, reported in Table I, were performed to determine the advantages and disadvantages of the two methods. The over-all average of lightweight material separated by skimming and decanting methods were identical, 8.6 per cent. It can be assumed that the average of several tests by either method would yield approximately the same results. The skimming method, however, is somewhat easier and safer in that there is less danger in spilling a beaker full of the dangerously toxic heavy liquid. This is particularly true when working with larger sizes of aggregate requiring the handling of 12-qt containers.

Considerable variation resulted between comparable tests in this initial series because retention time of the lightweight material in the heavy liquid and washing procedures were not identical. However, these variations indicated a need for the studies which followed.

Skimming and decanting of lightweight material from the heavy liquid was started immediately after immersing the samples in all tests shown in Table I, except for tests Nos. 3 and 6. In these two tests, skimming was delayed 10 min after the samples were immersed in the heavy liquids. Tests Nos. 2 and 3 and tests Nos. 5 and 6 are identical except for the delayed skimming. Note that in both the sink and float series, the delayed skimming resulted in separation of a lesser amount of lightweight material. Test No. 6, with a 10-min delay and 16 min total retention time, had less than half as much lightweight material separated as with the immediate skimming method of test No. 5. Apparently, in test No. 6, the lightweight particles absorbed some of the heavy liquid during the delay—enough in the case of some material to cause it to sink. It was thought that oven-dry samples would absorb the heavy liquid quicker than saturated surface-dry samples. For this reason and also because the specific gravity of concrete aggregate is based on the saturated surface-dry condition, tests Nos. 7 through 18 were made with saturated surface-dry samples. In these tests, an attempt was made to determine the average time required to thoroughly remove the lightweight material by both the decanting and skimming methods. The three sink and float samples required five and six decanting operations per sample, respectively, with an average of 6.5 min required. Removal by skimming averaged 4.0 min per sample.

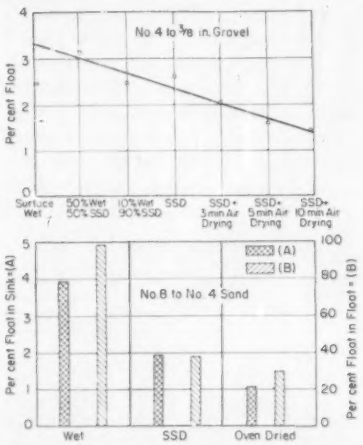

Fig. 8.—Excess surface moisture causes some heavyweights to float, some dry light-weights will quickly absorb heavy liquids and sink.

As a result of this test series, skimming was selected as a standard method of removing lightweight material principally because of safety, and, to a lesser extent, because of ease and shorter time required for perfomance.

Influence of Aggregate Moisture on Per Cent Lightweight Material

Thirty-three tests were made to determine the influence of aggregate moisture content on the separation of lightweight material from samples immersed in heavy liquid. This work was divided into two test series, the first using No. 8 to No. 4 sand the second series using No. 4 to $\frac{3}{8}$-in. gravel. The results of both series are shown in Table II and graphically in Fig. 8.

The tests clearly show that free moisture will cause some heavyweight material to float. This is especially true for sand samples; in fact, nearly all

TABLE I.—COMPARISON OF SKIMMING AND DECANTING METHODS.

Test	Type of Removal	Time in Liquids, min				Lightweight Material, per cent		Remarks
		Heavy Liquid	Perchloro-ethylene	Alcohol	Water	Individual	Average	
Oven Dry—Sink Samples								
No. 1	Decanting	Immediate	2	0	0	2.9	2.6	Decanting is somewhat more hazardous than skimming.
No. 2	Skimming	Immediate	0	1	5	2.4	...	
No. 3	Skimming	Delayed	0	1	1	2.2		
Oven Dry—Float Samples								
No. 4	Decanting	Immediate	2	0	0	13.9	15.1	Follows ASTM Method C 123-57 T, carbon-tetrachloride substituted for perchloro-ethylene.
No. 5	Skimming	Immediate	0	1	5	16.4	...	
No. 6	Skimming	Delayed	0	1	1	6.9		
Saturated Surface Dry—Sink Samples								
No. 7	Decanting	8	1	2	0	4.8		Decanting is slightly slower than skimming.
No. 8	Decanting	6	1	2	0	3.6	3.4	
No. 9	Decanting	5	1	2	0	1.6		Average time to decant all lightweight material = 6.5 min.
No. 10	Skimming	3	1	2	0	4.5		
No. 11	Skimming	3	1	2	0	5.8	4.4	
No. 12	Skimming	5	1	2	0	2.9		Average time to skim all lightweight material = 4.0 min.
Saturated Surface Dry—Float Samples								
No. 13	Decanting	7	3	3	0	15.9		Average results of both skimming and decanting are 8.6 per cent.
No. 14	Decanting	6	1	1	0	14.2	14.2	
No. 15	Decanting	7	1	2	0	12.0		
No. 16	Skimming	5	1	2	0	14.9		
No. 17	Skimming	4	1	1	0	11.1	12.7	
No. 18	Skimming	4	1	1	0	10.8		

(99.2 per cent) of the wet sand floated in tests No. 25 and 26. In tests of both sink and float samples, the tests with wet sand (Nos. 19, 20, 25, and 26) had more than twice the percentage of apparent lightweight material than tests with saturated surface-dry sand (Nos. 21, 22, 27, and 28), even though the sand for all of the samples was from the same source, blended and split so as to produce nearly identical samples. The film of free moisture around the sand particles was apparently not displaced immediately by the heavy liquid and occupied sufficient volume to lessen significantly the apparent specific gravity of the sand. Figure 8 shows that free moisture does not have such a pronounced effect on gravel as it does on sand-size particles. However, it does have the effect of increasing the apparent percentage of lightweight material sufficiently to show the importance of requiring close control against excessive free moisture.

To determine the difference in test results between sand samples in a saturated surface-dry condition and those in an oven-dry condition, tests Nos. 23, 24, 29, and 30 were made. Both sink and float samples showed that oven drying of sand reduces the apparent percentage of lightweight material over that obtained with saturated surface-dry sand. Apparently, some of the dry aggregates quickly absorb heavy liquid into the surface pores and sink. This same phenomenon occurs with partially dry gravel samples, as shown in results of tests No. 40 through 51.

The results of heavy-liquid control tests must be available to the heavy media plant operator as quickly as possible to permit rapid adjustments when necessary to avoid producing an excessive amount of sink product which will not meet the specifications requirements and, therefore, have to be wasted. Samples coming from the HMS plant are saturated and to oven dry them would require too much time. A saturated surface-dry condition can be reached in a much shorter period of time. For this reason and because of the rapid absorption of heavy liquid by oven-dry particles described below, a saturated surface-dry condition was selected for the standard heavy-liquid test.

Aggregate Absorption of Heavy Liquid

To determine the influence of absorption of heavy liquid by lightweight aggregate on the results of heavy-liquid tests, four float samples of No. 8 to No. 4 sand were immersed in heavy liquid and the quantities of lightweight material remaining afloat were determined at various time intervals over a 24-hr period. Two samples were oven dry and the other two were saturated surface dry. Initial lightweight particles floating to the surface of the heavy liquid were skimmed off immediately after turbulence due to immersion subsided, washed for 15 sec in alcohol to remove heavy liquid adhering to the surface of the particles, and reweighed in a saturated surface-dry condition. The samples were replaced in and allowed to

TABLE II.—AGGREGATE MOISTURE CONTENT.

Test	Moisture Condition	Removal Time, min	Lightweight Material, per cent: Individual	Lightweight Material, per cent: Average	Remarks
Sand (No. 4–8 Size)					
Sink Samples					
No. 19	Wet	5	4.2	4.0	Free moisture will cause sand heavyweights to float and may double percentage of lightweight material over saturated surface-dry samples.
No. 20		5	3.7		
No. 21	Saturated surface dry	5	2.2	1.9	
No. 22		5	1.6		
No. 23	Oven dried	5	1.3	1.0	
No. 24		5	0.8		
Float Samples					
No. 25	Wet	5	99.5	99.2	Oven drying causes some lightweight material to absorb heavy liquids and sink, but its effect on the percentage of lightweight material over saturated surface-dry samples is not as pronounced as is the effect of free moisture.
No. 26		5	99.0		
No. 27	Saturated surface dry	5	41.0	39.0	
No. 28		5	37.0		
No. 29	Oven dried	5	30.0	26.5	
No. 30		5	23.0		
Gravel (3/16 to 3/8-in.)					
Sink Samples					
No. 31	100 per cent surface wet	5	3.0	3.6	Effect of free moisture on gravel is not as great as it was with sand. However, it does increase the percentage of lightweight material over similar gravel in saturated surface-dry condition.
No. 32		5	2.2		
No. 33		5			
No. 34	50 per cent surface wet	6	3.0	3.5	
No. 35		8	3.5		
No. 36		8	3.9		
No. 37	10 per cent surface wet	7	2.4	2.6	
No. 38		7	1.5		
No. 39		5	3.8		
No. 40	Saturated surface dry	4	2.6	2.6	
No. 41		4	2.9		
No. 42		4	2.4		
No. 43	Saturated surface dry and 3 min drying time under fan	2	1.3	2.1	Drying gravel below saturated surface-dry condition decreases the percentage of lightweight material over similar gravel in saturated surface-dry condition.
No. 44		3	2.2		
No. 45		4	2.9		
No. 46	Saturated surface dry and 5 min drying time under fan	3	1.7	1.6	
No. 47		3	1.6		
No. 48		5	1.4		
No. 49	Saturated surface dry and 10 min drying time under fan	2	1.1	1.4	
No. 50		3	2.0		
No. 51		3	1.2		

Note: In all tests, lightweight materials were washed for 3 min in perchloroethylene and 2 min in alcohol.

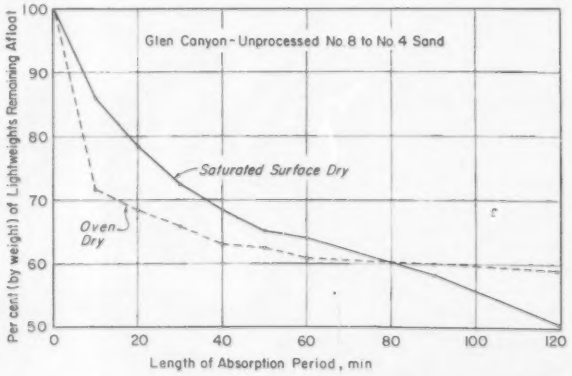

Fig. 9.—Lightweight aggregate particles floating in heavy liquids will absorb some of the heavy liquid, causing a large percentage of the initial lightweights to sink in a short period of time.

absorb the heavy liquid until the washing, drying, and weighing procedure was repeated at approximately 10-min intervals up to 1 hr. Additional tests were also made after 1½, 2, and 24 hr of absorption. During early absorption periods, the samples were agitated every 2 min. The time required to remove, drain, weigh, and return the lightweight particles to the heavy liquid was not included in the absorption periods shown with the test results in Table III and Fig. 9.

Figure 9 shows that the initial absorption rate is quite high and that 28 per cent of the oven-dry lightweight material absorbs sufficient heavy liquid to cause it to sink after soaking for only 10 min, whereas only 14 per cent of the saturated surface-dry lightweight particles sank after 10 min absorption, showing that the initial absorption of saturated surface-dry samples is only about one half that of the oven-dry samples. After 24 hr of absorption, about three-fourths of the initial lightweight material from both the oven-dry and saturated surface-dry samples had sunk. After 3 days, all particles had sunk. These tests show that the time of absorption permitted in the heavy-liquid test must be closely controlled. As a result, the heavy-liquid test requires that skimming start within 20 sec after the sample is immersed in the heavy liquid and be completed within 5 min thereafter.

Washing Aggregates to Remove Heavy-Liquid

The adherence of heavy liquid to the surface of lightweight particles removed during the heavy-liquid test increases the weight of the aggregate particles over their original weight in saturated surface-dry condition. Several methods of washing the liquids from the surface were tried with the objective of finding a quick method to return the lightweight particles to the surface-dry condition they were in when they were initially weighed out as a part of the total sample.

The results shown in Table IV indicate that any reasonable washing effort will give satisfactory results. In fact, it is only when an absorption period

TABLE III.—ABSORPTION OF HEAVY-LIQUIDS BY LIGHTWEIGHT MATERIAL.

Test	Absorption Period, min	Lightweight Material, per cent	Lightweight Material Remaining Afloat, per cent		Test	Absorption Period, min	Lightweight Material, per cent	Lightweight Material Remaining Afloat, per cent	
			Individual	Average				Individual	Average
Saturated Surface Dry					Oven Dry				
No. 52	0	19.0	100	100	No. 72	0	16.9	100	100
No. 53		22.1	100		No. 73		13.7	100	
No. 54	10	15.1	79	86	No. 74	10	11.5	68	71
No. 55		20.4	92		No. 75		10.3	75	
No. 56	20	13.6	72	78	No. 76	20	10.7	63	68
No. 57		18.4	83		No. 77		9.9	72	
No. 58	30	12.2	64	73	No. 78	30	10.5	62	66
No. 59		18.0	81		No. 79		9.6	70	
No. 60	40	11.6	61	68	No. 80	40	10.0	59	64
No. 61		16.7	76		No. 81		9.4	69	
No. 62	50	11.0	58	65	No. 82	50	9.7	57	62
No. 63		16.0	72		No. 83		9.2	67	
No. 64	60	10.7	56	64	No. 84	60	9.5	56	61
No. 65		15.8	71		No. 85		9.0	66	
No. 66	90	10.3	54	58	No. 86	90	9.5	56	60
No. 67		13.7	62		No. 87		8.7	64	
No. 68	120	9.5	60	50	No. 88	120	9.4	56	58
No. 69		11.3	51		No. 89		8.4	61	
No. 70	24 hr	3.2	17	23	No. 90	24 hr	4.1	24	25
No. 71		6.5	29		No. 91		3.7	27	

TABLE IV.—WASHING AGGREGATES TO REMOVE HEAVY LIQUID.

Test	Time in Heavy Liquid, min	Washing Time, min			Weight			Remarks
		Perchloroethylene	Alcohol	Water	g		Increase, per cent	
					Initial	Final		
HMS Sink Samples								
No. 92	15		Unwashed		405	414	2.0	Entire sample decanted and reweighed.
No. 93	15	0	5	5	404	407	0.7	
No. 94	15	5	5	5	405	406	0.2	
No. 95	15	6	4	0	715	716	0.1	
HMS Float Samples								
No. 96	5	1	1	0	404	406	0.5	Entire sample decanted and reweighed.
No. 97	5	2	1	0	404	405	0.2	
No. 98	5	3	2	0	404	404	0.1	
No. 99	5	4	3	0	405	405	0.1	
Unprocessed Samples								
No. 100	8		Unwashed		1000	1040	4.0	Entire sample decanted and reweighed.
No. 101	8	3	2	0	1000	1006	0.6	
Lightweight Samples								
No. 102	2		Unwashed		[a]	432	0.9	Lightweight material skimmed off and reweighed.
		3	2	0	[a]	428	0.0	
No. 103	2		Unwashed		[a]	403	1.2	
		3	2	0	[a]	398	0.0	

Note.—All samples were saturated surface-dry when weighed and immersed in heavy liquid.

[a] Float from 2000-g sample of unprocessed sand surface dried immediately on removal from heavy liquid, weighed, washed in solutions as indicated, surface dried and reweighed.

exceeding the adopted standard of 5 min is permitted that a serious error will result due to inadequate washing. To ensure a negligible error without excessively increasing the time to complete the test, a washing process of 3 min in perchloroethylene and 2 min in alcohol was selected for the procedure.

Consistency and Accuracy of Heavy-Liquid Test

Considerable variation exists between results of comparable individual heavy-liquid tests. Thirty-six tests were made to determine how much variation can be expected under carefully controlled conditions and how many tests should be performed before accepting or rejecting the sink product of an HMS plant. Results of tests are shown in Table V. Tests were made on both HMS treated and untreated sand and gravel. Maximum variation from the average of all tests on treated and untreated sand samples is 1.2 per cent and 1.8 per cent, respectively. However, by averaging consecutive tests into groups of three, the maximum group variation from the average for the treated series is only 0.1 per cent and that for the untreated series is only 0.2 per cent. From this, it was concluded that acceptance or rejection can very fairly be based on the average of three consecutive tests. Single tests are, of course, very useful in controlling the operation of the HMS plant.

Three tests were made with each size gravel fraction up to 1½ in. maximum for both treated and untreated gravels. Maximum variation occurs in the ¾ to 1½-in. fraction because a single 1½-in. lightweight particle may weigh over 5.0 g and exceed 1 per cent of the total sample. However, this size fraction is the easiest to treat and in all deposits investigated in the Bureau of Reclamation laboratories to date has contained only about ¼ to ⅓ as much lightweight material as the two smaller size gravel fractions.

Maximum variation in the two smaller gravel fractions was less than that for sand, and it was concluded that an average of three consecutive tests would be satisfactory for acceptance or rejection.

Summary and Conclusions

The Method of Test for Lightweight Material in Aggregate by Heavy-Liquid Separation, requires that the sample be saturated, surface dried, and weighed. It is then placed in a solution of 1,1,2,2,-tetrabromoethane and perchloroethylene having the required specific gravity. The sample is briefly agitated in the heavy liquid and as soon as the turbulence subsides, the lightweight particles floating on the surface are removed by skimming, washed in perchloroethylene and alcohol, surface dried, and reweighed.

It is important that care be taken to see that the samples are saturated surface dry when immersed in the heavy liquid. Wet samples will yield an apparent higher percentage; dry samples will yield an apparent lower percentage of lightweight material. This is particularly true for No. 4 to No. 8 sand and the finer sizes of coarse aggregate.

The specific gravity of the heavy-liquid solution should be checked before each test and adjusted when necessary. Perchlorethylene is more volatile than 1, 1, 2, 2,-tetrabromoethane, and this causes a mixture of the two solutions to become heavier in a comparatively short period of time.

Lightweight materials should be completely removed by skimming from the heavy liquid within 5 min after immersion therein to avoid excessive absorption of the liquid into the pores of the lightweight particles. A considerable amount of the lightweight material may sink in 10 min and, if left in long enough, all of it will sink.

Heavy liquid adhering to the surface of lightweight particles increases the

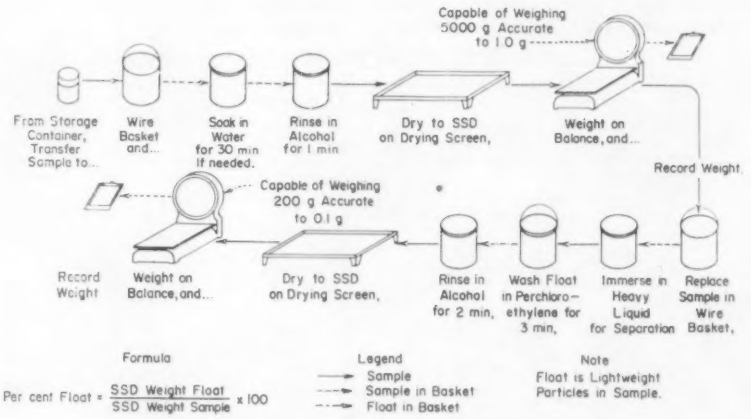

Fig. 10.—Flow diagram of heavy-liquid test to control the quality and efficiency of recovery of the sink product produced by the heavy media process.

TABLE V.—CONSISTENCY AND ACCURACY OF HEAVY-LIQUID TEST.

Test	Individual, per cent	Variation from Average, per cent	Lightweight, Average, per cent	Test	Individual, per cent	Variation from Average, per cent	Lightweight, Average, per cent
HMS Treated Materials				Untreated Materials			
No. 8 to No. 4 sand				No. 8 to No. 4 sand			
No. 104.	4.7	−0.8	5.5	No. 122.	14.6	−1.2	15.8
No. 105.	5.1	−0.4		No. 123.	16.2	+0.4	
No. 106.	6.7	+1.2		No. 124.	16.6	+0.8	
No. 107.	5.5	0.0	5.5	No. 125.	17.6	+2.0	15.6
No. 108.	5.0	−0.5		No. 126.	15.2	−0.4	
No. 109.	5.9	+0.4		No. 127.	13.9	−1.7	
No. 110.	4.9	−0.7	5.6	No. 128.	16.8	+0.8	16.0
No. 111.	6.1	+0.5		No. 129.	15.5	−0.5	
No. 112.	5.8	+0.2		No. 130.	15.6	−0.4	
Over-all average for treated sand = 5.5 per cent				Over-all average for untreated sand = 15.8 per cent			
No. 4 to ⅜-in. gravel				No. 4 to ⅜-in. gravel			
No. 113.	3.5	+1.0	2.5	No. 131.	19.3	+0.8	18.5
No. 114.	2.0	−0.5		No. 132.	18.6	+0.1	
No. 115.	2.0	−0.5		No. 133.	17.7	−0.8	
⅜- to ¾-in. gravel				⅜- to ¾-in. gravel			
No. 116.	1.5	−0.1	1.6	No. 134.	13.2	+0.8	12.4
No. 117.	1.2	−0.4		No. 135.	11.7	−0.7	
No. 118.	2.0	+0.4		No. 136.	12.2	−0.2	
¾- to 1½-in. gravel				¾- to 1½-in. gravel			
No. 119.	0	−0.6	0.6	No. 137.	1.9	−2.5	4.4
No. 120.	0	−0.6		No. 138.	7.4	+3.0	
No. 121.	1.8	+1.2		No. 139.	3.8	−0.6	

weight of the particles over their original weight in a saturated surface-dry condition. Washing the particles for 3 min in perchloroethylene and 2 min in alcohol will correct this condition. A flow diagram of the test is shown in Fig. 10.

Even under ideal laboratory conditions, considerable variation in test results may be expected between samples from the same source treated under identical conditions. Therefore, acceptance or rejection of treated materials which are borderline in quality should be based on the average of three or more tests.

This test, carefully performed, will serve as a rapid and safe method for controlling the efficiency and product quality of heavy media separation plants.

APPENDIX

SUGGESTED METHOD OF TEST FOR LIGHTWEIGHT MATERIAL IN AGGREGATE BY HEAVY-LIQUID SEPARATION

Scope:

This method of test covers a procedure for determination of the percentage of lightweight material in aggregate by means of sink-float separation in a heavy liquid of suitable specific gravity. This test is designed for 1000-g samples of sand passing the No. 4 sieve and retained on the No. 8 sieve and 5000-g samples of No. 4 to ¾-in. and ¾- to 1½-in. coarse aggregate size fractions. Samples should be representative of aggregate to be tested.

Chemicals:

(*a*) *Heavy Liquid.*—The heavy liquid shall consist of a mixture of 1,1,2,2,-tetrabromoethane (approximate specific gravity of 2.97) and perchloroethylene (approximate specific gravity of 1.63) in such proportions that the desired specific gravity may be obtained (NOTE 1.) When the specific gravity of the lightweight material is to be less than a specified specific gravity, the specific gravity of the heavy liquid shall be equal to the specified value. For example, if the specifications limit the amount of lightweight material having a specific gravity of less than 2.50 that may remain in the processed aggregates, the specific gravity of the heavy liquid shall be maintained at 2.50 throughout the test. (NOTE 2.) Figure 5 indicates the approximate proportions by volume of 1,1,2,2,tetrabromoethane and perchloroethylene for heavy liquids at various specific gravities.

(*b*) *Alcohol.*—The alcohol used for rinsing the lightweight aggregate fractions shall be denatured alcohol conforming to formula No. 1, 12A, 28A, or 30 of the U. S. Bureau of Internal Revenue.[2]

NOTE 1.—*Caution:* These liquids are highly toxic both by absorption through the skin and by inhalation. Tests should be performed in a well ventilated area, preferably under a hood, and care taken to avoid contact of the liquids with the skin or inhalation of the fumes. Use of protective clothing such as rubber gloves, rubber aprons, and goggles is advised.

NOTE 2.—Perchloroethylene is more volatile than 1,1,2,2-tetrabromoethane and the differential rate of evaporation causes a change in the specific gravity of the liquid mixture; hence, checking and adjustment of the specific gravity of the mixture is necessary before each test.

[2] Regulation No. 3 and appendix to Regulations No. 3 of the Bureau of Internal Revenue. These documents may be obtained from the Superintendent of Documents, Washington 25, D. C.

Apparatus:

(*a*) *Test Containers*

(*1*) *For Sand.*—Five 2-liter metal beakers each approximately 5 in. in diameter and two No. 10-mesh wire baskets with bail that will fit snugly, without binding, in the beakers.

(*2*) *For Coarse Aggregate.*—Five 12-qt metal beakers each approximately 10 in. in diameter and two No. 10-mesh wire baskets with bail that will fit snugly, without binding, in the beakers.

(*b*) *Skimmers.*—Two No. 10-mesh saucer shaped wire skimmers, 2-in.-diameter for sand, and 4.-in-diameter for coarse aggregate, both with handles.

(*c*) *Specific Gravity Measuring Apparatus.*—Hydrometers accurate to 0.01 and suitable for determining specific gravities of the heavy liquid, perchloroethylene, and alcohol. Hydrometer jars of sufficient size for hydrometer measurements.

(*d*) *Balances.*—A balance capable of weighing 5000 g accurate to 1.0 g and a balance capable of weighing 200 g accurate to 0.1 g.

(*e*) *Drying screen.*—One No. 10-mesh wire screen tray, 18 in. by 36 in. by 1 in. deep, with legs.

Preparation of Samples:

Obtain representative samples of approximately 1000 g of sand passing the No. 4 sieve and retained on the No. 8 sieve, and approximately 5000 g each of No. 4 to ¾-in. and ¾ to 1½ in. coarse aggregate size fractions. Wash as necessary to remove contaminating materials.

Procedure:

(*a*) *Separation.*—Place sample in appropriate wire basket and immerse basket with sample in water and soak for 30 min. (If the sample is already saturated, the soaking period will not be required.) Remove basket with sample and drain for 1 min. Place basket with sample in alcohol (NOTE 3.) Agitate sample by vertical up and down motion of the basket for 1 min. Remove basket with sample and drain excess alcohol. Transfer sample from basket onto drying screen, spreading sample one particle in thickness. Dry sample to saturated surface-dry condition (SSD). A saturated surface-dry condition exists when no free liquid remains on the surface of the particles. (NOTE 4.) Drying time to reach SSD condition may be reduced by use of a fan. Weigh SSD sample and record weight. Place SSD sample in wire basket and immerse in heavy liquid. (NOTE 3.)

NOTE 3.—Sand in 2-liter beakers containing approximately 1.5 liters of the liquid, and coarse aggregate in 12-qt beakers containing approximately 2 gal of the liquid.

NOTE 4.—*Caution.* Care must be exercised to ensure that the sand samples do not contain any free liquid when placed into the heavy liquids, since a film of liquid surrounding a heavyweight particle may cause it to float.

Stir the sample vigorously for 5 sec, allow 15 sec for turbulence to subside, and immediately skim off the floating particles. Skimming depth should be just sufficient to remove aggregate particles floating on the heavy-liquid surface. Care should be taken while skimming not to create undue currents in the liquid which would disturb the settled material. After skimming, allow excess heavy liquid to drain from skimmer back into beaker.

Transfer skimmed float material to appropriate wire basket. Repeat stirring and skimming sequence until all lightweight material has been removed and transferred to the basket. Skimming should be completed within 5 min from time sample is immersed in heavy-liquid.

(*b*) *Cleanup.*—Immerse basket containing the float material in a beaker containing perchloroethylene. (NOTE 3.) Agitate float material in beaker of perchloroethylene by vertical motion of basket for 3 min. Remove basket from beaker and drain excess perchloroethylene for 1 min. Remove remaining perchloroethylene by agitating basket in alcohol for 2 min. (NOTE 3.) Remove basket and drain excess alcohol for 1 min. The perchloroethylene and alcohol (rinse liquids) should be replaced whenever their specific gravity increases approximately 0.10. Transfer rinsed material to drying screen and dry to SSD condition as before. Weigh, and record weight.

Computations:

Calculate the percentate of float in the sample as follows:

$$\text{Float, per cent} = \frac{\text{SSD weight of float}}{\text{total SSD weight of sample}} \times 100$$

DISCUSSION

MR. D. O. WOOLF.[1]—I have two questions I would like to ask. First, how were the samples put in a saturated surface-dry condition; and, second, after the alcohol washing, what was the next treatment before weighing? Were they dried, and, if so, does that not remove the water that was absorbed?

MR. E. C. HIGGINSON (*author*).—The saturated surface-dry condition for an aggregate has been a problem for many years. We have tried several methods of determining just when an aggregate is saturated surface dry. It largely depends on the judgment of the operator. However, in the heavy media test, after soaking the materials for at least 30 min, we washed them in alcohol, thereby bringing about the saturated surface-dry condition faster. But there again it was the judgment of the operator as to when they were saturated surface-dry.

MR. DELMAR BLOEM.[2]—The toxicity of the heavy liquids and the rapidity with which the lighter of the two tends to evaporate have been mentioned. In our laboratory we have used as the lighter of the two liquids just ordinary Varsol, which is available at any filling station. It has three advantages. In the first place it is very cheap; in the second place, it is not nearly so volatile as carbon tetrachloride or the other light liquids; and, third, it is essentially nontoxic. We have been very well satisfied with it and perhaps it might remove some of the difficulties that were encountered with the other liquids.

MR. BRYANT MATHER.[3]—Were the gradings of the sink and the float fractions very different from each other or was the particle size distribution within the original sample and the sink and the float fractions about the same?

MR. HIGGINSON.—I would say they were about the same. In running the test, we separate the gravel into its size fractions, such as No. 4 to No. 8, No. 4 to $\frac{3}{8}$ in., and $\frac{3}{8}$ to $\frac{3}{4}$ in., so that we do not have a wide grading for the sample being tested. It works best, even in the production process, to work with somewhat near the same sizes so that the little particles do not ride "piggy-back" on the large particles.

CHAIRMAN E. W. CUMMINS.[4]—I would like to ask the author how he determines the specific gravity of the liquid?

MR. HIGGINSON.—With a hydrometer.

CHAIRMAN CUMMINS.—Where did you get the hydrometer?

MR. HIGGINSON.—I think there may be some difficulty in getting the right kind of hydrometer. I suspect that the one we use was made in the laboratory.

CHAIRMAN CUMMINS.—That must be so, because we can't find one.

This is somewhat outside the scope of your paper, but do you know of any instances where the heavy media process has been inverted to discard heavy deleterious particles?

MR. HIGGINSON.—No.

CHAIRMAN CUMMINS.—The deleterious particles in question were limonitic concretions whose specific gravity is somewhat higher than that of ordinary gravel. It was proposed by one of the companies concerned that if it were worth-while, they would develop a process by which the sink material was the undesirable material and the float was the good gravel.

MR. HIGGINSON.—It would be very useful for the aggregate for Glen Canyon Dam, as it contains some iron concretions which have a high specific gravity. Consequently, they are not removed by the heavy media process, yet they will cause pop-outs when they are near the surface of the concrete.

CHAIRMAN CUMMINS.—Does the cut of 2.50 remove all shale or was deleterious shale a problem in your aggregates?

MR. HIGGINSON.—I do not think that a medium with a specific gravity of 2.50 will remove all shales because some shales will run up to a specific gravity of 2.60.

CHAIRMAN CUMMINS.—But the shale content was brought down below the acceptance limit?

MR. HIGGINSON.—Yes. This process improves the aggregate. We do not say it cures it 100 per cent, because the sizes passing No. 8 sieve would still contain all of the float material and those little pieces on the surface will still cause scaling. We merely improved the aggregate greatly by the heavy media process; we do not make it perfect by any means.

MR. BRYANT MATHER.—A number of years ago an experimental run was made in which a gravel from the Missouri River was treated to remove both ends and save the middle. This was not done in commercial aggregate production but a carload or more was processed and tests were made on the fractions so produced. It was demonstrated that by taking off a relatively small percentage of the total that was lighter than 2.55 and heavier than 2.70, there was greater improvement of the middle than was obtained by taking off either end separately.

CHAIRMAN CUMMINS.—These were iron concretions?

MR. MATHER.—They were iron-bearing concretions in the heavy fraction and porous, lightweight, probably shaley, material in the light fraction.

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A Practical Method of Classifying All Elastomeric Vulcanizates*

By N. L. CATTON, R. C. EDWARDS, and T. M. LORING

THE NEED for a more complete coding and classifying system for elastomeric vulcanizates is well recognized. For several years, many technical groups have been working in this area. Such groups as ISO/TC 45, ASTM Committee D-11 on Rubber and Rubber-Like Materials, the Technical Committee on Automotive Rubber, and special groups working in the interests of the U. S. Department of Defense are all striving for the same goal, that is, to provide a workable system to classify and describe a wide range of qualities of commercially available elastomeric products. With the development of new elastomers and the ever-expanding technology in the use of present materials, the use of elastomeric materials for more severe service conditions becomes commonplace. Engineers and technologists are, therefore, continually faced with the complex problem of describing their new needs in terms that can be understood and fulfilled by the rubber industry.

Work in this area has been going on for almost two decades. In the early 1940's, a working group under the auspices of the Technical Committee on Automotive Rubber devised a classifying system for synthetic rubber compounds. The work of this committee resulted in the Tentative Specifications for Elastomer Compounds for Automotive Applications (ASTM D 735–SAE 10 R).[1] In 1944, DeFrance, then chairman of this working group, in a paper on "Specifications of Synthetic Rubber Compounds," presented as part of a Symposium on the "Applications of Synthetic Rubbers,"[2] described ASTM D 735–SAE 10 R, pointing out the basis for arriving at the quality levels for the various rubbers and illustrating to the consuming engineers how they could use this system to advantage in specifying their requirements.

Later, McCortney, then chairman of the Technical Committee on Automotive Rubber, presented a similar description of the use of ASTM D 735–SAE 10 R before the Society of Automotive Engineers.[3] Both of these papers were designed to explain a system that was then coming into use. It was generally agreed that there was a need for such a system in the automotive industry, and a sincere effort was made to use the new system. The system of ASTM D 735–SAE 10 R is still in use after serving the automotive and rubber industries well for nearly two decades, but it is obvious to those working closely with it that it is approaching the end of its usefulness in its present form.

In Technical Committees 45 on Rubber of the International Standards Organization[4] attention has been called to the limitations of a tabular system such as ASTM D 735–SAE 10 R, and attempts have been made toward establishing a broader, more comprehensive means of accomplishing the classification of rubber vulcanizates. Those concerned with the problems of the American automotive industry have objected to the proposals under con-

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NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

* Presented before the International Rubber Conference, Washington, D. C., November 8–13, 1959.

[1] 1959 Supplement to Book of ASTM Standards, Part 9 (ASTM D 735), and 1959 SAE Handbook (SAE 10 R).

[2] M. J. DeFrance, "Specifications for Synthetic Rubber Compounds," Symposium on Applications of Synthetic Rubbers, *Am. Soc. Testing Mats.*, p. 39 (1944). (Issued as separate publication *ASTM STP No. 61.*)

[3] W. J. McCortney, Presentation before Society of Automotive Engineers, Detroit, Mich.

[4] International Standards Organization, Technical Committee 45 on Rubbers, Documents 398–400.

sideration principally from the view that they permit, or even encourage, the specifying by consumers of impractical combinations of properties, and they do not furnish sufficient guidance to the user.

Proposed Expanded Tabular System

The following basic principles guided the work that led to the development of the Expanded Tabular System, described in this paper.

1. The system must be flexible enough to accommodate future new elastomers,

2. It must be flexible enough to accommodate new methods of test and requirements,

3. It must supply guidance to the user in the selection of practical commercial compositions, and

4. The system must restrict the inexperienced from specifying impossible and impractical combinations of physical properties.

In arriving at a system accomplishing these purposes, it is well to have a clear understanding of the inherent advantages of a tabular system and of the "line call out" technique. A "line call out" is a convenient method of specifying a quality desired in an elastomeric composition. It offers simplicity in communication, especially in defining the desired quality on engineering drawings, contracts, and correspondence. The "line call out," however, to have significance, *must* come from a tabular system listing the various combinations of properties that are commercially available. Tables of properties in themselves are only a classification. A "line call out" for a specific quality becomes a specification. No combination of properties, however, should be included in any table until they can be supplied in practice. Tables are the only practical means of listing a large number of physical properties together with the values for those properties resulting from established methods of test.

In ASTM D 735–SAE 10 R, there are at present six tables. If tables were established for all of the currently available elastomers, this number would be increased substantially, and the classification would soon become impractically large and confusing. The proposed Expanded Tabular System provides complete and adequate classification in *two* tables—one, a table listing properties that should be met by all properly formulated and vulcanized elastomeric compounds for normal use, and the second, a table of suffix requirements which enables the purchaser to select and specify the particular quality he needs. The system provides guidance in the selection of practical commercial compositions and can be readily expanded to take care of future new materials and requirements. The Expanded Tabular System satisfies the requirements previously listed for any successful classification system.

TABLE I.—BASIC REQUIREMENT—ESTABLISHING TYPE BY TEMPERATURE.

(Heat aging—70 hr)

Type	Temperature	
	deg Cent	deg Fahr
A	70	158
B	100	212
C	125	257
D	150	302
E	175	347
F	200	392
G	225	437
H	250	482

TABLE II.—BASIC REQUIREMENTS—ESTABLISHING CLASS BY VOLUME SWELL.

(Oil aging—ASTM No. 3 Oil—70 hr)
(Temperature determined by type except 302 F max)

Class	Volume Swell, per cent
A	0 to 6
B	7 to 15
C	16 to 35
D	36 to 75
E	76 to 150
F	151 and up

TABLE III.—TYPE-CLASS POLYMER CORRELATION.

NOTE.—Some elastomers will fulfill requirements of two or more classes because many of these names cover a family of products varying in composition. Furthermore, each elastomer is capable of a wide range of compounding and vulcanization modification. For example, while most neoprene compositions would be BD, others might be BC or BE or even CD, CC, or CE. Other materials may vary similarly.

Class	Type									
	A	B	C	D	E	F	G	H	J	K
(*)—A	...	...	...	...	..	..	...	Viton[a] Fluorel[b]	..	..
(*)—B	...	Polysulfide	...	...	..	..	...	...	..	..
(*)—C	...	NBR Urethane	...	Polyacrylate	..	..	...	...	..	..
(*)—D	...	Neoprene	Hypalon[a]	...	..	..	Silicone	...	..	..
(*)—E	...	...	...	...	..	..	...	...	..	..
(*)—F	Rubber	SBR, Butyl	...	...	..	..	...	...	..	..

* This space to be filled with a letter indicating type, which together with the letter indicating class forms the letter symbol designation for the material.

[a] Registered trademark E. I. du Pont de Nemours & Co., Inc.

[b] Registered trademark Minnesota Mining & Manufacturing Co.

TABLE IV.—BASIC CLASSIFICATION TABLE.

Type	A							G						
Material	AF							GC						
			Heat Aged 70 hr at 158 F			Oil Aging No. 3 Oil 70 hr at 158 F				Heat Aged 70 hr at 437 F			Oil Aging No. 3 Oil 70 hr at 302 F		
Hardness No.	Tensile Strength, min, psi	Ultimate Elongation, min, per cent	Change in Tensile Strength, max, per cent	Change in Ultimate Elongation, max, per cent	Change in Hardness, points, max	Volume Swell, per cent	Compression Set, 22 hr at 158 F, max, per cent	Available Subclasses	Ultimate Elongation, min, per cent	Change in Tensile Strength, max, per cent	Change in Ultimate Elongation, max, per cent	Change in Hardness, points, max	Volume Swell, per cent	Compression Set, 70 hr at 437 F	Available Subclasses
30 ± 5	500	X	±30	−40	±15	Over 151	X	All	X	±30	−40	±15	+16 to +35	X	All
	1000	X					X	All	X					X	All
40 ± 5	1500	X					X	All	..					..	..
	2500	X					X	1, 2	..					..	..
60 ± 5	700	X					..	All	X					X	All
	2500	X					X	1, 2, 3	..					..	..

X indicates values available.
.. indicates no values available.

There are certain basic concepts that underlie the proposed system. All elastomeric vulcanizates can be broadly separated and classified by their resistance to dry heat and to petroleum hydrocarbon oils. Polymers are generally considered in terms of their inherent stability with respect to heat and oil. Moreover, it has been generally established by recent work that it is practical to consider that changes in physical properties after a specified period of aging are constant. This applies regardless of the original hardness or tensile strength level of the composition.

The first step then is to provide a means of separating elastomeric vulcanizates into *types and classes* for purposes of grading. In the Expanded Tabular System segregation as to type is based on the resistance of any vulcanizate to changes in tensile strength of not more than ±30 per cent, elongation not more than −40 per cent, and hardness not more than ±15 points, after air oven aging for 70 hr at an appropriate temperature. In Table I are listed the temperatures at which elastomeric vulcanizates shall be tested for determining type.

All types are further separated as to class on the basis of their resistance to swelling in a petroleum hydrocarbon (ASTM No. 3 Oil) after 70-hr immersion at a temperature determined from the type table, except that a maximum temperature of 302 F (the upper limit of oil stability) shall be used. A listing of the limits of swelling for each class at various test temperatures is shown in Table II.

Using these methods for determining type and class of any elastomeric vulcanizate, it is immediately apparent that natural rubber vulcanizates become Type A, Class F, thus becoming Grade AF. The letter designation symbols "A" for type and "F" for class would always be written together as "AF" material, in each case the first letter signifying type and the second letter denoting class. Therefore, "AF" would replace the present Type R, Non-Oil Resistant class of ASTM D 735–SAE 10 R. Similarly, Type B, Class BD, written "BD," would replace Type S, Class SC.

In Table III is suggested an *approximate* type and class designation for the present commonly available elastomers. This is based on the generally accepted industry performance records for the elastomers defined in the Recommended Practice for Nomenclature for Synthetic Elastomers and Latices (ASTM Designation: D 1418).[5]

Using this system of typing and classifying all elastomeric vulcanizates, a Basic Classification Table can be established as shown in Table IV. The

[5] 1958 Book of ASTM Standards, Part 9.

TABLE V.—SUFFIX REQUIREMENT TABLE.

Subclass	Material	Suffix A				Suffix B		Suffix C		Suffix E								Suffix F		Suffix R		
		A42		A43		B12	B13	C1	C2	E13				E43				F15	F16	Resilience at 20 per cent Deformation		
		Change in Tensile Strength, max, per cent	Change in Ultimate Elongation, max, per cent	Change in Tensile Strength, max, per cent	Change in Ultimate Elongation, max, per cent	Change in Hardness, points, max	Compression Set, max, per cent	Resistance to Outdoor Aging	Resistance to Ozone	Change in Tensile Strength, max, per cent	Change in Ultimate Elongation, max, per cent	Change in Volume, per cent limits	Change in Hardness, points, max	Change in Tensile Strength, max, per cent	Change in Ultimate Elongation, max, per cent	Change in Volume, per cent limits	Change in Hardness, points, max	D 746 Brittleness Temperature (−40 F)	D 746 Brittleness Temperature (−67 F)	Hardness 40	Hardness 60	Hardness 70
1..	AF	±30	−40	±30	−40	±15	50	Yes	Yes	...	...	...	...	...	...	...	...	Yes	Yes	75	60	50
2..	AF	±15	−20	±15	−20	±10	25	Yes	Yes	...	...	...	...	...	...	...	...	No	No	75	60	50
1..	BC	...	...	±30	−40	±15	75	No	No	...	...	...	...	...	...	+16 to +35	...	Yes	No	...	...	...
2..	BC	...	...	±15	−20	±10	35	No	No	−20	−40	−10 to +5	−10 to +5	−35	−40	0 to +25	−10 to +5	Yes	No	...	...	...
3..	BC	...	...	±15	−20	±10	40	No	No	−30	−50	−15 to 0	0 to +15	−35	−40	0 to +18	±5	Yes	Yes	...	...	...
1..	BD	...	...	±30	−40	±15	80	Yes	Yes	...	...	...	...	...	...	+36 to +75	...	Yes	Yes	...	...	...
2..	BD	...	...	±15	−25	±10	40	Yes	Yes	−30	−30	±10	±10	−70	−55	+0 to +50	−35	Yes	Yes	...	...	...

first two vertical columns in the table list the hardness of the compound and its tensile strength, which may be expressed in either the metric or English system of units. Following these two columns are other columns to describe the elongation and basic deterioration after dry heat aging and after immersion in a petroleum hydrocarbon with values as shown in Tables I and II for type and class designation. When the operation of this system becomes familiar through experience, the inclusion of basic values for indicating type and class will be understood, and, therefore, deleted from the Basic Classification Table, thus further simplifying the table. A basic compression set value column is given with values as an additional means of defining proper degree of vulcanization. The last vertical column under each class lists the "available subclasses." The importance and use of this column as applied to the table of suffix requirements will be considered later.

Any given vulcanizate, therefore, may be characterized from the Basic Classification Table as to type and class, type of composition referring to its generally accepted level of heat resistance, and class referring to its degree of swelling by oil. Then the type and class will be expressed by a two-letter symbol.

For many applications, it will be adequate to specify only the basic characteristics of a composition. But for the great majority of uses, further definition of quality will be necessary. This may be readily done by using the values shown in the Suffix Requirement Table (Table V). This is basically a consolidation of all of the present suffix requirements in use in ASTM D 735–SAE 10 R. However, numerous refinements and condensations have been made to simplify the Expanded Tabular System and to make it easier to use.

A material is carried from the Basic Classification Table to the Suffix Requirement Table only by its letter symbols for type and class and its subclass. An example of the structural setup of the Suffix Requirement Table is shown in Table V. At the left are two vertical columns covering each class and its respective subclasses: for example, 1AF, 2AF, 1BC, 2BC, 3BC, etc. The suffix requirements are then arranged horizontally and alphabetically from left to right in vertical columns. These suffix requirements use the same letter designations as in ASTM D 735–SAE 10 R.

Two suffix numbers follow the suffix letter and indicate the method and temperature of test. The first suffix number always indicates the method of test. Time of test will always be a part of the method of test. The second suffix number will always indicate the temperature test. Suffix numbers are assigned to the various methods of test involved. For heat aging tests, which may be conducted by either the oven method or by the test tube method, suffix numbers are shown in Table VI. In either case, Suffix A would indicate heat aging tests and would have the suffix number assignments shown.

TABLE VI.—HEAT AGING.

Suffix Number	ASTM Method
1.....	D 865— 22 hr
2.....	D 865— 70 hr
3.....	D 865—168 hr
4.....	D 573— 70 hr
5, 6, etc....	Other types as necessary

Similarly, compression set Suffix Requirement B will have suffix numbers assigned as shown on Table VII:

TABLE VII.—COMPRESSION SET.

Suffix Number	ASTM Method
1.....	D 395—22 hr
2.....	D 395—70 hr
3, etc....	Other types as necessary

For oil resistance, Suffix Requirement E, suffix numbers will be assigned as shown in Table VIII:

TABLE VIII.—OIL AGING.

Suffix Number	ASTM Method
1.....	D 471—Oil No. 1— 70 hr
2.....	D 471—Oil No. 1—168 hr
3.....	D 471—Oil No. 2— 70 hr
4.....	D 471—Oil No. 3— 70 hr
5.....	D 471—Oil No. 3—168 hr
6.....	D 471—Oil No. 4— 70 hr
7.....	D 471—Ref. Fuel A—70 hr
8.....	D 471—Ref. Fuel B—70 hr
9.....	D 471—Ref. Fuel C—70 hr

For low temperature tests, Suffix Requirement F, suffix numbers will be assigned as shown in Table IX:

TABLE IX.—LOW-TEMPERATURE CONDITIONING.

Suffix	ASTM Method
1.....	D 746 —
2.....	D 1053—
3.....	D 1229— 22 hr
4.....	D 746 — 22 hr
5.....	D 746 —168 hr
6.....	D 746 —...
7.....	D 1053—168 hr
8.....	D 1229— 94 hr

Suffix letters "C" for ozone resistance or weather aging, "K" for adhesion, "R" for resilience, and other suffixes will be handled in a similar manner, that is, by establishing a listing of the applicable test methods, thus giving meaning to the first suffix number following the suffix letter.

For temperature conditioning tests applicable to Suffix Requirements A, B, E, and F, a set of suffix numbers has been established as shown in Table X:

TABLE X.—SUFFIX TEMPERATURE CONDITIONING TABLE.

Applicable Suffix Requirements	Suffix Number	Conditioning Temperature, deg Cent	Conditioning Temperature, deg Fahr
A, B, E..	9	250	482
	8	225	437
	7	200	392
	6	175	347
	5	150	302
	4	125	257
	3	100	212
	2	70	158
	1	23	75
F.....	2	0	32
	3	−10	14
	4	−20	− 13
	5	−40	− 40
	6	−55	− 67
	7	−75	−103

These numbers have the same meaning, namely, a test temperature designation, regardless of the aging suffix to which they are applied. These test temperature suffix number designations are the only ones that apply to suffix letters A, B, E, and F, and they are the second number following the letter.

A further subdivision of each Suffix Requirement column (Table V) is made to define the individual physical property changes required. In some cases, these columns will consist of a percentage change in tensile strength and ultimate elongation and an actual points change in hardness. In some cases, the column will contain an actual numerical value that is required, and still other cases, the word "yes" or "no" will be used to indicate whether the subclass composition described meets the test or requirement shown. Then the values of the required properties are positioned in the table opposite the appropriate class and subclass designations.

Subclass 1, listed in front of the class designation (1BCXXX), as a prefix would mean that all requirements in the Basic Classification Table must be met. Suffix requirements, in addition to the basic heat and oil requirements available on the horizontal line in the Suffix Requirement Table, may be added. Subclass numbers greater than "1" mean that all quality requirements *must come* from the Suffix Requirement Table, and that the values in the Basic Classification Table *are not necessarily* applicable. No suffix requirements can be specified without the use of a subclass prefix number. Through the use of subclass designations, the listing of quality levels both above and below the basic standard are now practical. It is by means of the subclass designations that guidance is offered to the inexperienced against the possibility of asking for impossible combinations of properties.

If it were not for the subclass designation, there would be a tendency to use suffixes intended for one class to describe desired properties in another class. This would lead to specifications containing impractical combinations of properties. *Because of this, only values for suffix requirements which appear on the horizontal line opposite a subclass can be specified.* Selections of values in a vertical direction cannot apply.[6] Theoretically, a given class could have an infinite number of subclasses. The actual number will depend upon the number of quality levels required by industry.

We now have a Basic Classification Table, a Suffix Requirement Table, and a method for determining the *type* and *class* for any given elastomer vulcanizate. The practical use of this system will, therefore, depend upon being able to specify a particular quality level by means of a "line call out." First, the specifying engineer must decide what quality he wants and convert this to a type and classification consideration. He then must establish the proper location of his required composition in the Basic Classification Table. For example, if he wished to specify a rubber compound for a simple grommet, he could use only the Basic Classification Table, such as, AF515. These three-digit numbers indicate the durometer hardness and the tensile strength of the material. The first number, 5, indicates 50 ± 5 hardness, the second two numbers, 15, indicate tensile strength, as 1500 psi minimum, etc.

Either natural rubber or SBR, depending upon economics, could be furnished against this requirement. As another example, let us assume that the engineer wants a product for service at 212 F. It is, therefore, a Type B. Further, he wants a material swelling no more than 25 per cent in ASTM No. 3 Oil. It becomes a Class C material. He has now established the fact that he wants a BC material. From a knowledge of the hardness and the tensile strength level required, he can write the basic requirement as 1BC715, for example. By using the prefix number "1" the use of suffix requirements may be selected from the Suffix Requirement Table.

Because the application is critical, he decides that the basic requirements do not provide sufficient safety to meet peak operating temperatures. From the Suffix Requirement Table, he finds that he can either tighten the limits at 212 F or specify a higher temperature aging level. He decides to tighten the limits specified at 212 F. This is done by calling for Subclass 2, which describes a much more heat-resistant composition. He now writes 2BC715A43 as his specification. If he decides to raise the temperature, he chooses the type of material having the next higher level of heat resistance. In this case, he selects 257 F test temperature, which gives him a Type C material without changing the level of oil resistance. He now has a CC material.

For another similar use, he is interested in having a low set at a temperature of 212 F, so he specifies Suffix B13 in addition to 2BC715A43. He is interested in maximum resistance to oil at 212 F, and he does not wish a stock that will have a negative swell. For this, he requires the addition of Suffixes E13 and E43. This gives him the following specification in a "line call out": 2BC715A43B13E13E43. For ease in transcription, on typewriters and other automatic equipment, the "line call out" is written on one horizontal line. Examples are as follows:

1AF515
2BC715A43
2BC715A43B13E13E43

By this means, any quality level of elastomeric vulcanizate can be specified. If suffix requirements or temperature levels other than those now provided for are needed in the future, they can be added without changing any existing values. Similarly, suffix requirements for low-temperature properties, resilience, staining, etc., as now used in ASTM D 735–SAE 10 R can be integrated into the Expanded Tabular System and be shown in any "line call out."

Summary

In summary, to meet the need for a universal and simplified system of classifying and coding elastomer vulcanizates, we have described an Expanded Tabular System, which provides flexibility in respect to elastomers, quality levels, and methods of test. Guidance to the consumer in helping him to avoid specifying impossible or impractical combinations and indicating to him those quality levels which are commercially available is provided by the tables. Where no value exists in the table, it means that no composition is available with that particular combination of properties or that no composition having those properties has yet been needed by the industry.

We have shown that it is possible to classify all elastomer vulcanizates as to *type* in terms of their resistance to change after air oven aging at elevated temperatures and as to *class* in terms of their resistance to swelling in ASTM No. 3 Oil. With this system of basically classifying materials together with the requirements available from the Suffix Requirement Table, it is possible to describe any given quality by means of a "line call out" specification.

While the Expanded Tabular System has been presented using engineering units common in the United States, the system is not limited to these units and can be readily expressed in units common to the metric system.

Work in the Technical Committee on Automotive Rubber is progressing toward the adoption of this system. Some phases are pretty well advanced. This system has the flexibility necessary to satisfy the requirements of the U. S. Department of Defense, and active work has been going on for the past several months in the preparation of a master classification system for the Department of Defense based on the Expanded Tabular System. The practical use of this system would be to supply a master listing of all of the compositions available, and then make it possible for each procuring agency to issue specific purchasing specifications describing only the qualities in which they are interested. This same principle could apply to any other purchasing organization.

[6] These safeguards are important in restricting the inexperienced person from improper use of the suffix requirements. However, should it be desirable for research purposes, it would be possible to apply values for suffix requirements selected from more than one horizontal line. The resultant line call out would undoubtedly be impractical and not commercially available. However, it would provide the necessary language to describe unique and unusual requirements for guidance in development and research work.

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> Firms Spur Camera Use To Solve Test, Sales, Production Problems

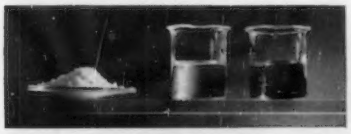
headlined the first column of *The Wall Street Journal* on the penultimate morning of last summer.

"Industry sources expect retail sales of equipment and supplies for industrial photographic use will reach some $250 million this year, up from about $100 million five years ago," the story said. (That's a very short time ago. These very discourses have been appearing for six years in this periodical.)

Feeling well disposed toward *The Wall Street Journal*, we laid it aside and took action to maintain the trend. Of "supplies" that *The Wall Street Journal* mentioned, none is older than photographic plates—our original product. For the love of challenge, we decided to get ready for the printer a chart that would put the photographic plate right into the spearhead of photography's onslaught on current technology.

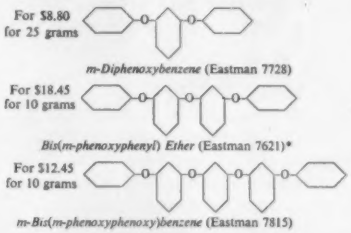
The chart is now ready. You may have a copy with our compliments for your photo department wall. Indicate interest to Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y. It takes 29" x 16½" to set out enough information about our 75 species of plates to permit industry and technology some intelligent basis for choice. You will receive the chart accompanied by a little pamphlet on dimensional stability entitled "Physical Characteristics of Kodak Glass Plates." Gist of the pamphlet's message: if there were no such thing as the glass photographic plate, it would be necessary to invent it.

600°F is tougher than 350°F



To demonstrate how passably these two liquids and this solid perform as oxidation-, corrosion-, and radiation-resistant lubricants for gears and bearings operating up to 600°F in flying objects and other up-to-date kinds of machinery must have taken a tidy chunk of government money. We can cluck like a frugal taxpayer, since only a pittance found its way into our pockets.

Now that the pure, undoctored, unsubstituted meta-linked polyphenyl ethers are revealed to rate high for chemical sturdiness, lubricity, and retention of the liquid state over a broad temperature range, we find it in our hearts to enable the experimenter to acquire them in a small, quiet commercial transaction without diplomatic maneuvering.



Perhaps one of our markets for these polyphenyl ethers will be for use as foils against which to demonstrate the superiority of new classes of lubricants as yet unrevealed, just as the polyphenyl ethers stand up for many hours to conditions that devastate 350°F lubricants to stiff sludges or vapors in minutes. Two decades ago, when we were in the high-vacuum business and considered ourselves pretty smart in diffusion pump liquids, we developed some phlegmatic esters that now serve as the goats for the polyphenyl ethers to beat.

Small, quiet transactions are the mainstay of the Eastman Organic Chemicals Department of Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company). Our current "List No. 41" will tell you of our organic chemical wares, some 3700 of them.

Less than a laundry

Our subsidiary, Recordak Corporation, has recently come out with a portable microfilmer that weighs only 24 pounds and lists for only $845. Do you ask what this has to do with science? Then we are wracked by ambivalent feelings toward you. On the one hand, we feel extra respectful in your presence; a mind so obviously unaccustomed to seek solace in gadgetry is scarce. At the same time, we want to turn you gently toward the light. Certainly you're not the type to seek your solace in paper-shuffling, but you have to prove that, if only to yourself.

Think for a moment like that fabled monster, the efficiency expert. His baleful eye casts about for concentrations of paper. When he sees information being extracted from one pile of papers for summary on yet another piece of paper, his mouth waters. When he sees some poor soul toiling at a task that could go undone but for the necessity of preserving proof of the finer details, he pounces. Our subsidiary, Recordak Corporation, watches from the bushes and purrs benevolently. Get the picture?

It all began in banks a generation ago, spread to department stores and phone companies, and in the last decade has reached enterprises like dry-cleaning establishments, dairies, and medical clinics. Now the idea of microfilming while summarizing has been brought down to the scientist's level. The *Recordak Portable Microfilmer* is of the right scale in size and cost for work of lesser magnitude (from Recordak's special viewpoint) than getting out the monthly statements of a prosperous laundry.

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Recordak Corporation, 415 Madison Avenue, New York 17, N. Y., has a nationwide chain of branch offices and processing stations. It is just possible that your problem will remind the salesman of one he solved for the wholesale chicken business and that he will take you out and show you how it works there.

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*There has been some 40° to 800°F talk about this one.

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

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FROM THE CURRENT MATERIALS NEWS

Creep of Solid Propellants

Though creep properties are most commonly thought of in connection with metals, they are also important in the evaluation of viscoelastic materials, such as rubber or plastics. Solid rocket propellants are viscoelastic, and measurement of their creep properties gives important information regarding their mechanical behavior. By observing changes in the creep behavior of propellants as they age, one can infer a number of things about the chemical processes involved.

Under a Wright Air Development Center project concerned with the aging behavior of solid propellants, an improved method for creep measurement was devised by Stanford Research Inst. In conventional creep tests, weights are usually suspended from a specimen to load it in tension. The downward movement of the weights is observed at time intervals until a rate-of-deformation curve is determined. Observations are made visually and are thereby time-consuming and subject to human error because of the minute quantities involved. Further, additional time is required to plot the data. Most important, it is not usually possible to determine accurately the initial portion of the curve—that is, where the distinction is made between the reversible elastic properties of the material and its irreversible creep deformation.

In the apparatus developed at SRI, measurements are made continuously and automatically by a differential transformer. Deformation is recorded on a strip-chart recorder. Consequently, the device saves a great deal of observation time and is considerably more accurate, with measurements to 0.005 in. possible.

The new device can also measure stress relaxation. In this test, a constant deformation is introduced mechanically at the time the specimen is placed in the test machine. The decay or relaxation of stress is then measured by automatically recording the output of a dynamometer consisting of a strain ring and a differential transformer.

The information gained from this more accurate measurement of creep and stress relaxation is expected to contribute significantly to the knowledge of the mechanical behavior of propellants and of propellant aging processes.

Research for Industry,
Stanford Research Inst.,
Sept.-Oct., 1959

Nuclear Power for Remote Installations

The Atomic Energy Commission has awarded a contract to Kaiser Engineers, division of Henry J. Kaiser Co., Oakland, Calif., for a study of the potential use of nuclear power at remote military installations.

Under the contract, the company will compare the cost of conventional power with the estimated cost of nuclear power for military installations which expect to need new generating capacity of 5000 to 40,000 kw during the period 1963–1970. Kaiser will also designate the most suitable type of reactor for each installation and recommend the most economical method of construction. The latter might include: on-site assembly and erection of components, plant fabrication with minimum on-site assembly and erection, and off-site construction on a floating mount such as a raft or barge. Reactor types to be considered include those systems that are technically well defined and proved at present or can reasonably be expected to be proved by the time construction would begin.

Results of the study will be submitted to AEC by February 1, 1960. The report will include cost estimates and construction schedules for each plant, detailed capital and operating cost estimates for both nuclear and conventional plants for each of the ten most nearly economic combinations of remote-application nuclear power plant types, and descriptions of proposed methods of construction.

Saving Miss Liberty

In 1938, the Statue of Liberty, in the entrance to New York City's harbor, was dangerously close to falling apart because corrosive attack had weakened the rivets holding its huge metal plates together. It was saved then by pulling the plates up tight with 65,000 Monel screws. Today, after more than 20 years' service, these screws show little sign of corrosion.

White Metal Newsletter,
The International Nickel Co., Inc.
Oct., 1959

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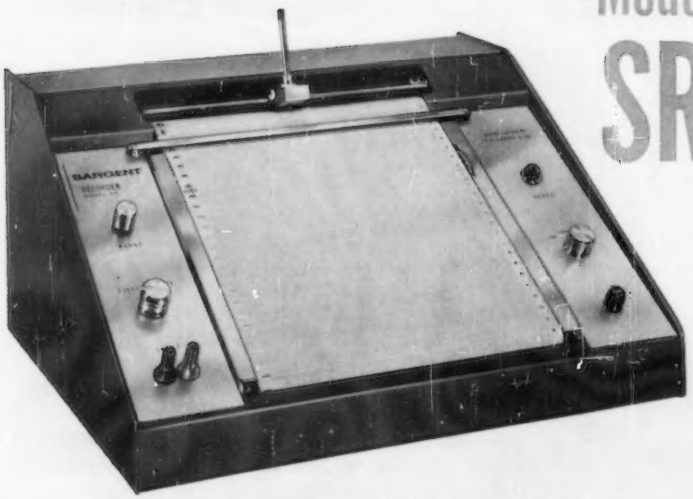

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Copies of these books are not available through ASTM; all inquiries concerning them should be addressed to the publisher.

Proceedings of the First International Skid Prevention Conference

Virginia Council of Highway Investigation and Research, Box 3817, University Station, Charlottesville, Va.; 600 pp.; $10.

THIS PUBLICATION, in two parts, contains a total of 59 papers with discussions. The papers cover the following areas:

- Kinds of skidding and accidents involving skidding,
- The human element in skidding,
- Relationship of vehicle dynamics to skidding,
- The relationship of tire design and composition to skidding,
- Laboratory and field methods of measuring road surface friction,
- The relationship of road surface properties to skidding, and
- A comparison of several methods of measuring road surface friction.

In addition, these Proceedings contain the reports of the five conference subcommittees which set forth the latest findings and recommendations in the areas listed above.

Bonded Aircraft Structures

Ciba (A.R.L.) Ltd., Duxford, Cambridge (1957); 177 pp.; Illus.; 8½ by 11; $7.50.

THE SIXTEEN papers in this volume were presented at a conference arranged by Aero Research Ltd., Duxford, Cambridge, in 1957. The authors are fourteen European and two American experts on various phases of adhesive bonding of aircraft structures.

The material, presented largely at a very practical level, forms the first publication of its kind to cover so comprehensively the entire field of bonded aircraft structures. It presents a wealth of useful design, test, process, and theoretical information about this subject and should be of great interest to aircraft and materials engineers, students, and believers in adhesive bonding.

The sponsors of the conference and publishers of the book (A.R.L.) are widely known throughout the world, particularly in Europe, for their two famous structural adhesives, Redux and Araldite. Much of the book, therefore, is concerned with these two adhesives, but much is also applicable to metal adhesives in general. The planning and arrangement of the book are such that the entire field is covered in excellent detail from the fundamentals of adhesion through production methods, design, testing, and inspection. This same format has also been used successfully by the director of Aero Research Ltd. and chairman of the Conference, N. A. DeBruyne, in his two earlier books, written in 1951, *Adhesion and Adhesives* and *Structural Adhesives*.

Numerous photographs and charts appear on practically every page, illustrating the most up-to-date bonding techniques and information presently available. These have been reproduced in excellent detail. However, the fine, narrowly spaced type on large-area glossy paper is somewhat hard on the eyes.

This book is highly recommended as a compact reference of recent origin.

STEVEN YURENKA

(*Continued on p. 83*)

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FOR FURTHER INFORMATION CIRCLE 439 ON READER SERVICE CARD

BOOKSHELF

(*Continued from p. 80*)

Aluminum Construction Manual

The Aluminum Association, 420 Lexington Ave., New York, N. Y., 1st ed., August, 1959; 389 pp.; $3.00. Illus.

THE publication of this manual is indicative of the growing importance of aluminum and its alloys to the construction industry. Structural designers now have available a manual on aluminum construction that is comparable to the steel construction manuals. The user of this manual should read the first few pages of the introduction headed, "Some Things the Designer Should Know," which points out the differences between the aluminum alloys and steel and enumerates the advantages and disadvantages of aluminum construction.

The manual is well organized in four parts. Part 1 contains such information as dimensions, weights, section elements, and tolerances for structural shapes, rod, bar, and tubing. Part 2 contains estimating and detailing information. This is a rather miscellaneous section that contains a considerable amount of information essential to structural design. Part 3 is a tabulation of allowable loads on beams and columns. These have been calculated for all of the standard structural shapes that are commercially available. Part 4, "Standards and Specifications," contains the ASCE specifications for structures of aluminum alloys 6061-T6 and 2014-T6, and also contairs tabulations of the mechanical property limits of the structural aluminum alloys. Part 5, "Miscellaneous Data," is a very useful section containing such information as physical and mechanical properties of structural materials, effect of elevated temperatures on aluminum alloys, coefficients of expansion of structural materials, frequently used structural formulas, and many mathematical tables.

All in all, this should be an extremely useful handbook for anyone interested in structural design using aluminum alloys.

I. V. Williams

Eye, Film, and Camera in Color Photography

Ralph M. Evans; John Wiley & Sons, Inc., New York, N. Y.; 422 pp.; Illus.; $8.95.

THOSE WHO know Ralph M. Evans, since 1947 director of the Color Technology Division of Eastman Kodak Co., would expect that his name as the author of a book would insure an outstanding publication. Probably no one who works in the field of color photography would deny that this, his latest book, is a major addition to the numerous publications in this field.

A member of ASTM and active in several committee projects, Mr. Evans has spoken at Society meetings and at

(*Continued on p. 84*)

(*Continued from p. 83*)

sessions sponsored by many other organizations. Much of this book is a compilation of these lectures.

With 16 pages of illustrations in color and hundreds of excellent black-and-white pictures and sketches, the book is splendidly illustrated. From the opening sentence in his chapter on the nature of color photography, which reads "Photography is today one of the most powerful known means of communication," until his closing comments about individual style, almost 400 pages later, there is a great wealth of very practical and useful information for the amateur, the professional, and the semi-professional.

Mr. Evans is one of our most articulate scientists, and virtually everything he covers—and few important things are not covered—is easily grasped. His main purpose is to encourage people to use photography as a truly creative medium. To this end, he first discusses the nature of color photography, then he tells how we see things and how the camera sees things. This is followed by some very practical information on color and form and the perception of light and color in photographs. He next describes how color photography works, tells something of the subject and intention in photography and what this permits the photographer to do. He spends some time on printing, and then the closing chapter treats photography as a creative medium.

Mr. Evans devotes considerable space to illumination and to depth of field. He writes that one of the most powerful tools available to the photographer is the variable depth of field that can be produced by changing the lens aperture, yet this technique seems to be little used or appreciated. Although most of us do not, every amateur and semi-professional should, before he snaps the shutter, perhaps ask himself "what about depth of field?"

The book is made more valuable by a 19-page bibliography and a sufficiently detailed table of contents and subject index. Considering the expenditures that many of us make for camera, supplies, lenses, film, etc., it seems to this reviewer—not exactly a novice in the field of color photography—that an investment in this book would be well worth-while.

R. J. P.

A Concise Encyclopedia of World Timbers

F. H. Titmuss; The Philosophical Library, Inc., New York (1959); 264 pp.; $15.

THE STRUCTURE, characteristics, and uses of nearly 200 different kinds of timbers originating in every part of the world are described in this second and newest edition of this book. This compilation literally provides information from A to Z in timbers—Abura, found in Equatorial Africa, to Zebrawood, one species of which is found in French Guiana.

The new edition includes nearly all the matter in the original edition together with a number of new commercial timbers available to world markets. This material is presented in a very concise manner with a page devoted to each timber. The inclusion of photomicrographs covering some 30 woods has added greatly to the usefulness of the book.

The volume should be a valuable addition to the libraries of the many firms and individuals whose livelihood depends on the growing, the distribution, or the use of timber.

L. C. GILBERT

Ferrites (Physical Properties of Ferrimagnetic Oxides in Relation to Their Technical Applications)

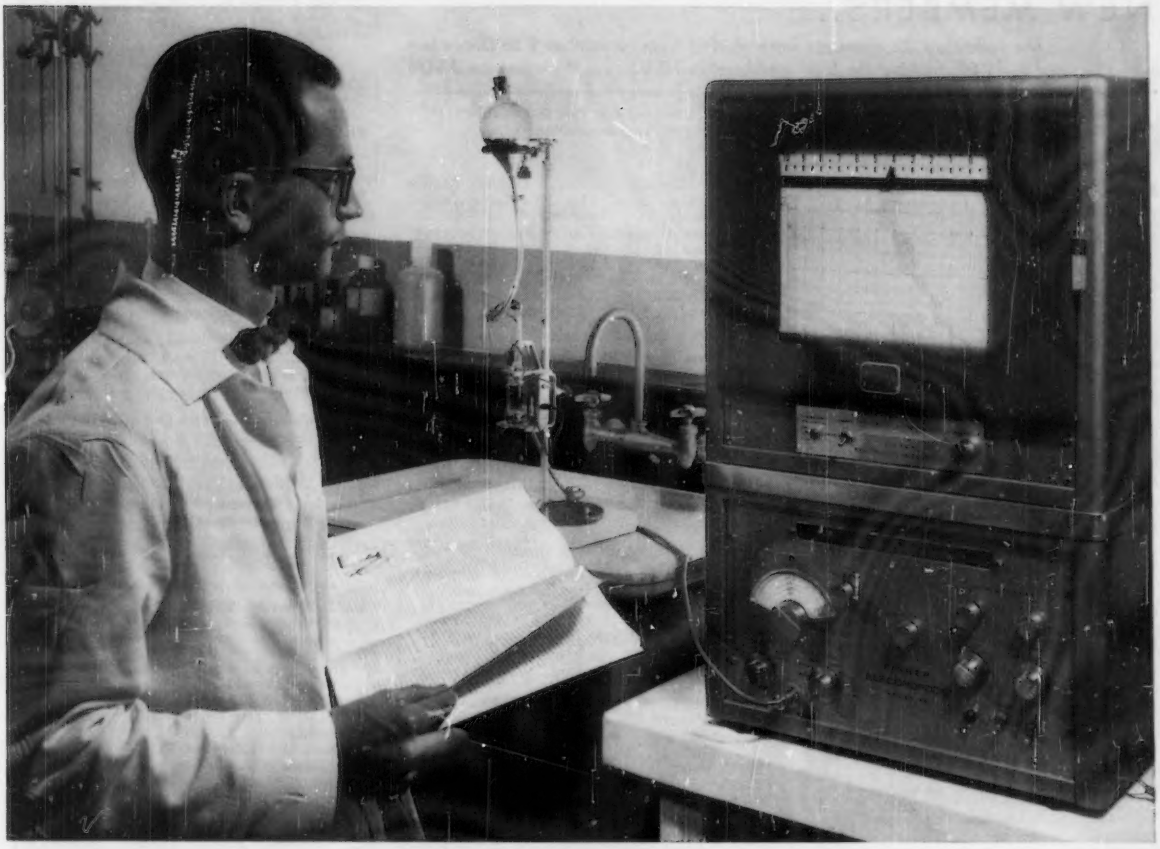
J. Smit and H. P. J. Wihn; John Wiley & Sons, Inc., New York, N. Y. (1959); 366 pp.; Illus.; $10.

IT IS A pleasure to read this book on ferrites. It ties together comprehensively all the loose ends of the many individual articles that are spread throughout the literature so that the reader obtains a clear picture of all the intricacies of ferrite structure and behavior.

Not as a judgment of value, but rather as a matter of point of view, it must be stated that the subtitle of the book (Physical Properties of Ferrimagnetic Oxides in Relation to Their Technical Applications) seems to be not quite appropriate. In fact, the gap unfortunately still existing between physics and engineering comes to light if one looks at the book from an engineering standpoint, which would be implied by "applications." Whereas the physicist is essentially interested in the intrinsic or primary properties of ferrites, the engineer works with secondary or bulk properties of ferrites. The book is written more for physicists and makers of ferrites. The practicing engineer often may not have the time to study in detail all the complex mechanisms that determine the properties of ferrites. He wants a more explicit presentation of what is implied in the book. The electronics engineer is more circuit-oriented than he is materials-oriented. The discrepancy between the physicist's and engineer's approach also becomes quite obvious in the chapter on measurements. For instance, for loss measurements at large amplitudes and higher frequencies, the use of the convenient Fluke wattmeter as used in industrial laboratories is not mentioned.

Using a phrase coined by Prof. Arthur von Hippel of Massachusetts Institute of Technology, this book may possibly be best described as being in the field of "molecular engineering" of ferrites, in which "engineering" is used in a wider sense than in our previous statements. With access to the vast amount of theoretical and empirical knowledge acquired at the Philips Laboratories, the authors are in a position to discuss authoritatively the interrelations of chemistry and crystal

(*Continued on p. 89*)



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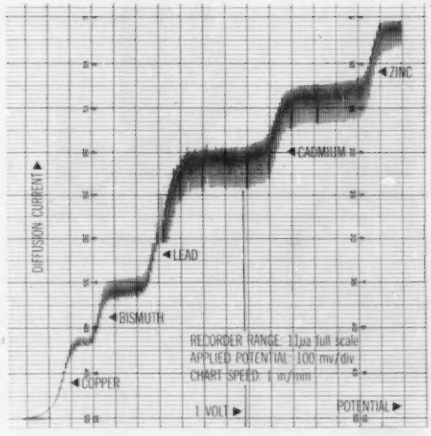

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FOR FURTHER INFORMATION CIRCLE 446 ON READER SERVICE CARD

NEW MEMBERS...

The following 32 members were elected from November 9 to December 10, 1959, making the total membership 10,062...Welcome to ASTM

Note—Names are arranged alphabetically—Company members first then individuals—
Your ASTM Year Book shows the areas covered by the respective Districts.

Chicago District

Mercoid Corp., The, Thomas W. Crawford, Engineering Dept., 4201 Belmont Ave., Chicago 41, Ill.

Engstrom, John A., engineering standards manager, American Hoist and Derrick Co., 63 S. Robert St., St. Paul 7, Minn.

Gilbert, S. G., laboratory manager and staff assistant to director, Research and Development, Milprint, Inc., 4200 N. Holton St., Milwaukee 1, Wis.

Keirans, Joseph A., chief engineer, R-B-M Controls Div., Essex Wire Corp., Logansport, Ind.

Wold, Howard E., chief structural engineer, Schmidt, Garden & Erikson, 104 S. Michigan Ave., Chicago 3, Ill.

Cleveland District

Lamberton, Bruce A., chief engineer, Intrusion-Prepakt, Inc., 568 Union Commerce Bldg., Cleveland 14, Ohio.

New England District

M & C Nuclear, Inc., Marvin M. Turkanis, chief metallurgist, Box 898, Attleboro, Mass.

Gilman, Charles M., vice-president, The Gilman Bros. Co., Gilman, Conn.

Locke, Edward B., Jr., chief engineer, Continental Screw Co., New Bedford, Mass. For mail: 109 N. Walnut St., Fairhaven, Mass.

New York District

British Ropes (New York), Inc., E. G. Hodder, secretary, 18 South St., New York, N. Y.

Metliz, Daniel, partner, Daniel Metliz Associates, 31-07 21st St., Long Island City 6, N. Y.

Whitener, Ernest Karl, Jr., supervisor, Corrugated Container Section, Product Development Laboratory, Union Bag-Camp Paper Corp., 400 Ninth St., Hoboken, N. J.

Ytterberg, C. Frederick, president, Kalman Floor Co., 110 E. Forty-second St., New York 17, N. Y.

Ytterberg, Robert F., vice-president, Kalman Floor Co., 110 E. Forty-second St., New York 17, N. Y.

Pittsburgh District

Burrell Construction and Supply Co., Paul Boff, technical director, 1 Fifth Ave., New Kensington, Pa.

Shannon, Walter L., director of pipe line engineering, Gulf Oil Corp., Box 1166, Pittsburgh 30, Pa.

Rocky Mountain District

Noonan, Norbert G., mechanical engineer, Engineering Consultants, Inc., 1901 S. Navajo St., Denver 23, Colo.

St. Louis District

Barco, Robert G., assistant chief engineer, Rawlings Manufacturing Co., 2300 Delmar Blvd., St. Louis 3, Mo.

Gross, A. F., vice-president, Missouri Paint and Varnish Co., 5125 N. Second St., St. Louis 7, Mo. For mail: 9709 Duke Dr., St. Louis 21, Mo.

McCadden, John E., Jr., manager, Mastic Div., Steelcote Manufacturing Co., 3418 Gratiot St., St. Louis 3, Mo.

Popeck, Charles A., chief test engineer, A. B. Chance Co., 210 N. Allen, Centralia, Mo. [A]*

Southeast District

Engineering Laboratories, Inc., Leon Hollifield, vice-president and director, 400 N. E. Third Ave., Fort Lauderdale, Fla.

Florida, State of, Division of Corrections, Paul A. Skelton, Jr., deputy director for business affairs, 243 Carlton Bldg., Tallahassee, Fla.

Roberts, Charles W., soils engineer, Soiltest Div., Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill. For mail: 1109 Columbiana Rd., Birmingham, Ala.

Southern California District

Benioff, Ben, partner and structural engineer, King, Benioff and Associates, 14906 Ventura Blvd., Sherman Oaks, Calif.

Sherman, Harvey, staff engineer, Space Technology Laboratories, Box 95001 Airport Station, Los Angeles 45, Calif.

Western New York-Ontario District

Lundy, Homer S., consulting engineer, 3426 Lundy's Lane, Niagara Falls, Ont., Canada.

Shields, Julian W., staff engineer, Engineering and Construction Dept., Union Carbide Metals Co., Division of Union Carbide Carbon Corp., 430 Buffalo Ave., Niagara Falls, N. Y.

Other Than U. S. Possessions

A.C.I. Plastics Proprietary Ltd., J. B. Williamson, manager, Great South Rd., Penrose, Auckland S.E. 6, New Zealand.

Société Marroco-Italienne de Raffinage, Ahmed Benkirane, president, Box 211, Rabat, Morocco, East Africa.

Harriss, Noel Richard Henry, managing director, R. H. Harriss (Pty.), Ltd., Box 2551, Johannesburg, South Africa.

Ottawa, University of, J. C. Beauchamp, professor of strength of materials, Department of Civil Engineering, Ottawa, Ont., Canada.

* [A] denotes Associate Member.

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DATA SHEET No. 2

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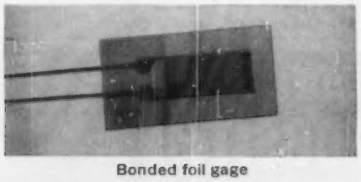
When the need arises, however, many engineers without specific background in strain-gage techniques find themselves on unfamiliar ground in attempting to select the best gage for the job from over 250 available types. Although it is important to the validity of the results that the gage used be properly suited to the application, selection is normally not a difficult matter and depends principally on known test conditions and on the nature of the data required. When the following criteria have been established, a suitable gage type for a specific application may be readily selected from the SR-4® Catalog.



Bonded foil gage

1. Temperature—The temperature at which the test is to be conducted is an important (frequently limiting) factor in determining suitable grid and base materials. At room and moderately high temperatures, both wire and foil gages are used. At temperatures above 350°F (and at very low temperatures), foil gages must be used. Some types are available with a backing material which may be stripped off during application, the grid alone being bonded to the test area. Such gages may be used up to 1400°F (for dynamic-type tests).

SELECTION OF GAGE MATERIALS BASED ON TEMPERATURE

Maximum Temperature (°F)	Base Material		Filament Material
180	Paper, Bakelite, Epoxy		Any
250	Bakelite, Epoxy		Any
350	Bakelite		Any
600	None	Strippable backing	Constantan or Nichrome foil
1000*	None		Nichrome foil
1400* (dynamic only)	None		Nichrome foil

*Limit imposed by available bonding adhesives

2. Test duration—For short-term tests (a few days) at temperatures below 150°F, paper-base gages are satisfactory and are usually more economical than other types. Extra-thin paper gages speed the curing of the bonding cement for fast application. For longer test periods (months or years), phenolic (Bakelite) or epoxy-base gages are usually used.

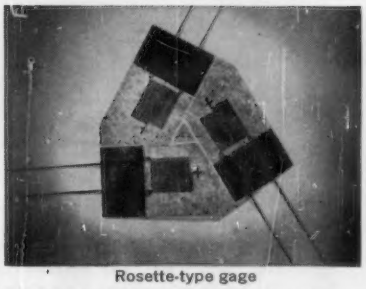
Dual-lead-type gages, with intermediate lead joints, provide good fatigue life. For better fatigue resistance and minimum hysteresis foil gages are advisable. They exhibit combined hysteresis and zero shift of less than 0.10% in strain reversals of up to ±1.5%, have generally higher fatigue resistance than equivalent wire gages.

3. Strain type and magnitude—For static strains, gages having grids of Constantan are usually used up to 600°F. For dynamic strains—particularly those of small magnitude—isoelastic gages are often recommended because of their relatively high strain sensitivity and improved fatigue resistance. Their high sensitivity to temperature change, however, limits usage to the measurement of vibratory strains unless appropriate precautions can be taken to cancel out or allow for this effect. When static strains of high magnitude (±2% to ±10%) are involved, a "post yield" gage is used.

4. Test-area geometry—Gage size depends primarily on the test space available. In general, the largest gage possible should be used. The probable strain gradient of the test area should also be considered, since the strain gage essentially averages the surface strain beneath its grid. When the test space is curved, foil gages are recommended, since they are flexible and will readily assume almost any continuous contour. When small wire gages are used, the new fine-pitch, flat-grid types are generally superior to "wrap-arounds".

5. Strain direction—Single-grid gages are used when the direction of the principal strain to be measured is known. If the strain field is biaxial and the directions are known, a 90°, 2-element rosette gage may be employed. When the strain field is unknown, a 3- or 4-element rosette may be used to determine the direction and magnitude of principal strains.

6. Output requirements—The required gage resistance and sensitivity are frequently dictated to some extent



Rosette-type gage

by the sensitivity of the measuring system to be used. Maximum gage output can be achieved by using a high-resistance gage with maximum bridge voltage.

7. Temperature compensation requirements—Strain gages are sensitive to changes in temperature as well as strain. This temperature effect on the measuring gage can often be canceled out by use of an unstressed "dummy" gage sensing identical temperatures and connected in the strain-gage circuit. In cases where a dummy gage cannot be used, some form of *self*-temperature-compensation is required. There are three general types of temperature-compensating strain gages available.

a. Self-temperature-compensating wire gages—individually compensated for specific materials and specific temperature ranges.

b. "Selected-melt" foil gages—with grids produced from a "melt" of strain-sensing material specifically selected for minimum temperature response over a specific temperature range.

c. Self-temperature-compensating foil gage—a recently developed grid design with an appropriate external circuit, which may be adjusted to provide minimum temperature response on any desired material over any temperature range.

For Engineering Assistance

When tests involve unusual conditions (e.g., high frequencies, strong magnetic or radiation fields, etc.) or necessitate special gage configurations, unusually accurate data, etc., it is advisable to consult your local SR-4® Strain Gage Sales Engineering Representative. He can also supply you with information and specific recommendations on strain-gage instrumentation (static and dynamic), cements, waterproofing compounds, and other accessories.

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FOR FURTHER INFORMATION CIRCLE 448 ON READER SERVICE CARD

BOOKSHELF

(*Continued from p. 84*)

structure with the properties of ferrites, the word "ferrite" being used as a generic term for magnetic oxides containing iron as a metallic component; garnets and oxidic permanent magnets with hexagonal crystal structures are included. Development of ferrites not originating from Philips Laboratories are treated rather briefly. This seems to be fair, since the authors point this out in the Foreword.

In brief, this book, with its extensive bibliography, represents an excellent monograph of ferrites from the point of view of the materials man.

H. M. SCHLICKE

AEC Lets Contracts for Advanced Nuclear Power Plant

The Atomic Energy Commission has signed contracts with the Philadelphia Electric Co. and General Dynamics Corp., who will develop and build an advanced, high-temperature, gas-cooled, nuclear power plant. Operation of this plant, at higher, more efficient temperatures than those in plants now operating or under construction, promises to accelerate the achievement of economic nuclear power.

The plant will include a graphite-moderated, helium-cooled, nuclear reactor, designed to produce 40,000 net kw of electrical power. The plant will be constructed by Philadelphia Electric Co., at Peach Bottom, Pa., under the AEC's Power Demonstration Reactor Program. It is expected to be completed by Oct. 1, 1963. General Dynamics' General Atomic Division, in San Diego, Calif., will conduct the pre- and postoperation research and development for the reactor.

Under the Philadelphia Electric contract, the AEC will waive $2,000,000 fuel-use charges through the first five years of operation. Philadelphia Electric Co. will be responsible for the design and construction of the nuclear power plant, which will cost $24,500,000.

Design and construction cost will be shared by Philadelphia Electric Co. and the 51 other utilities comprising the High-Temperature Reactor Development Associates, Inc., a nonprofit organization for research and development in the field of nuclear energy.

The fuel elements will consist of uranium and thorium dispersed in graphite and will be graphite-clad. Metal-clad fuel elements may be used for the initial core of the prototype plant, since they require less research and development. If metal-clad elements are used, they will be replaced by graphite-clad elements after enough information is available to establish the feasibility of using a graphite-clad core. The graphite-clad core should reduce power costs.

NEWS OF MEMBERS...

News items concerning the activities of our members will be welcomed for inclusion in this column.

Several ASTM members were among those who were honored and received prizes at the recent convention of the American Society of Civil Engineers: **Frank H. Masters,** senior partner, Modjeski and Masters, Harrisburg, Pa., a 50-year member of ASTM, was elected an Honorary Member; **Charles R. Foster,** coordinator of research, National Bituminous Concrete Assn., Washington, D. C., was co-winner with Willard J. Turnbull of the Norman Medal, the oldest and most coveted of ASCE's awards, for their paper entitled "Stabilization of Materials by Compaction"; **Bramlette McClelland,** partner, Greer & McClelland, Houston, Tex., was co-winner with John A. Focht, Jr., of the James Laurie Prize for their paper, "Soil Modulus for Laterally Loaded Piles"; **F. E. Richart, Jr.,** professor of civil engineering, University of Florida, Gainesville, Fla., received the Thomas A. Middlebrooks Award for his paper, "Analysis for Sheetpile Retaining Walls"; and **D. B. Steinman,** consulting engineer, New York, N. Y., received the Ernest E. Howard Award, citing him "for his signal contribution towards the advancement of bridge analysis and design, to the theory of the suspension bridge and its aerodynamic stability, and especially for his outstanding work in the design of the Mackinac Bridge."

Among the newly elected officers of the Association of Consulting Chemists and Chemical Engineers are the following ASTM members: **Carl Bussow,** chief chemist, A. W. Dow, Inc., New York, N. Y., president, and **Emerson Venable,** consulting chemist and engineer, Pittsburgh, Pa., treasurer.

K. A. Arnold, prior to becoming director of research and development, St. Regis Paper Co., Deferiet, N. Y., was technical director, Central Technical Dept.

Samuel A. Abrahams, consulting engineer, Berkeley, Calif., has been appointed by the United Nations to serve as magnesium resources expert on a three months' technical assistance mission to Israel.

Dan Bailey is now design engineer, National Cash Register Co., Inglewood, Calif. He had been a consulting engineer with Capitol Service Co., Santa Monica, Calif.

Howard M. Bixby, formerly field engineer, National Crushed Stone Assn., Inc., Washington, D. C., is now project management engineer, International Cooperation Administration, Washington, D. C.

Charles J. Chaban, research director in charge of coated and processed fabrics, The Landers Corp., Toledo, Ohio, has been promoted to vice-president for research.

Harmer E. Davis, professor of civil engineering and director, Institute of Transportation and Traffic Engineering, University of California, Berkeley, Calif., is concluding a year's service as chairman of the Highway Research Board. Last year, Prof. Davis received the annual Roy W. Crum award for distinguished service, in recognition of his contributions to education, research, and public service in the field of highway transportation.

Charles R. Funk was named chief metallurgist, Eastern Div., Colorado Fuel and Iron Corp., Claymont, Del. He was manager, metallurgy and engineering, Alco Products, Inc., Latrobe, Pa.

David P. Griffith was named vice-president, operations, Hercules Cement Co., Division of American Cement Corp., Philadelphia, Pa. He had been plant manager.

Alfred W. Hopton, formerly owner of Niagara Industrial Laboratories, Niagara Falls, N. Y., is now chemist, Hooker Chemical Corp., Niagara Falls, N. Y.

Louis J. Jacobs, former research director, was appointed vice-president, manufacturing and research, The Ramtite Co., Division of The S. Obermayer Co., Chicago, Ill.

(*Continued on p. 92*)

DON'T GUESS—

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(ASTM Proc., Vol. 55, 1955)

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FOR FURTHER INFORMATION CIRCLE 455 ON READER SERVICE CARD

NEWS OF MEMBERS

(*Continued from p. 90*)

J. Peter Kass recently joined the staff of Armour & Co., Chicago, Ill., in the newly created position of director, Central Research Laboratories. He had been director of research, Pabst Laboratories, Milwaukee, Wis.

Theodore J. Kauer, executive vice-president and chief engineer, The Holmes Construction Co., Wooster, Ohio, has been named director of public works for Ohio.

Augustus B. Kinzel has been appointed chairman, Division of Engineering and Industrial Research, National Academy of Sciences–National Research Council Washington, D. C. Dr. Kinzel is vice-president for research, Union Carbide Corp.

Marvin Lane, technical director of Graver Water Conditioning Co., Division of Union Tank Car Co., New York, N. Y., was named general manager of the division.

C. P. Larrabee has been appointed chief research engineer, corrosion prevention, United States Steel Corp., Monroeville, Pa. He had been in the Applied Research Laboratory.

E. E. Laughlin is now manager, Aerolite Co., Dayton, Ohio. Previously he was technical assistant to staff management, Bendix Aviation Corp., Kansas City, Mo.

G. A. McCammon is now project manager, Esso Standard (Libya), Inc., Tripoli, Libya. He was division chief engineer, Creole Petroleum Corp., Caracas, Venezuela.

James K. McConville, previously chief metallurgist, Accurate Die Casting Co., Cleveland, Ohio, is now affiliated with The Basic Aluminum Castings Co., Cleveland, Ohio, as metallurgist.

Guy F. McCracken, chief control metallurgist, Crucible Steel Co. of America, Midland, Pa., has been named division superintendent, technical services.

Robert F. Mehl, dean of graduate studies and head of the department of metallurgy at Carnegie Institute of Technology, will become a consultant for scientific liaison between its research organization and various universities and research institutes in Europe. Prof. Mehl is a former chairman of Committee B-2 on Non-Ferrous Metals and Alloys.

Robert C. Meissner has been named president of Meissner Engineers, Inc., Chicago, Ill. Previously he was executive vice-president.

Egon Orowan, George Westinghouse Professor of Mechanical Engineering at Massachusetts Institute of Technology, was awarded the Bingham Medal by the Society of Rheology. He was honored for his work in the behavior of solids, particularly his contribution to the understanding of the phenomena of plastic flow.

Enno H. Page is engineering trainee, Doehler-Jarvis Div., National Lead Co., Toledo, Ohio. He was electronics technician, Burroughs Corp., Detroit, Mich.

R. G. Picard has been elected a vice-president of Central Scientific Co., Chicago, Ill. He had been director of research.

Walter H. Price, head, Engineering Laboratories, United States Bureau of Reclamation, Denver, Colo., received the Department of the Interior's highest honor, the Distinguished Service Award, in recognition of outstanding contributions in the field of engineering with the Bureau of Reclamation. The citation, signed by the Secretary of the Interior, Fred A. Seaton, lists many developments in the field of concrete mix design and construction methods to which Mr. Price contributed. Much of the work has been related to the work of ASTM Committee C-9 on Concrete and Concrete Aggregates, of which Mr. Price is chairman. He has been a member of ASTM since 1946 and is also active on Committees C-1 on Cement and E-10 on Radioisotopes and Radiation Effects.

Walker Reynolds, vice-president, Alabama Pipe Co., Anniston, Ala., retired Sept. 1, 1959. Mr. Reynolds was a long-time member of Committee A-3 on Cast Iron.

Jerome F. Saeman has been appointed chief of the Division of Wood Chemistry at the U. S. Forest Products Laboratory, Madison, Wis.

Ernest Schweizer retired recently from the Celanese Corporation of America, Summit, N. J., where he served as senior research associate. Mr. Schweizer, in addition to representing his company's sustaining membership in the Society, held individual membership since 1945. He will retain his membership and continue to participate in the work of Committee D-20 on Plastics.

Ronald E. Shaw, formerly process engineer, Rockwell-Standard Corp., Newton Falls, Ohio, is now process engineer, Ontario Steel Products Co., Ltd., Chatham, Ont., Canada.

Leslie E. Simon has resigned as vice-president and director of research and development, Carborundum Co., Niagara Falls, N. Y. He will be a staff director of research and development, acting in a consulting capacity to the president.

Norman H. Spear is associated with Olympic Plastics Co., Los Angeles, Calif., as general manager. Previously he was research physicist, Continental Can Co., Chicago, Ill.

William T. Sterling, formerly soils engineer, E. Lionel Pavlo, New York, N. Y., is now with Standard-Vacuum Oil Co., White Plains, N. Y., as asphalt and soils engineer.

G. P. Tschebotarioff, professor of civil engineering, Princeton University, Princeton, N. J., has been awarded the degree *Docteur honoris causa* of the faculty of ap-

(*Continued on page 95*)

NEW **PUSH-BUTTON** SIMPLICITY REVOLUTIONIZES TENSILE TESTING

THE SCOTT MODEL CRE Constant-Rate-of-Extension Tester offers you the ultra-high accuracy of inertialess electronic weighing . . . *plus* effortless automatic operation that takes the work and weight handling out of physical testing! At a touch, the simple finger-tip controls of the Model CRE provide a variety of crosshead speeds, complete crosshead control and a wide range of test capacities . . . enabling even the non-technical operator to obtain detailed test results faster, easier, and *at amazingly low cost!*

VERSATILITY, is another time- and money-saving feature of the Scott CRE Tester. This simple yet super-sensitive tester is designed for use with Scott's more than 150 different clamps and holding fixtures to meet ASTM, ISO and Industry Test Methods and material requirements. Moreover, Model CRE can be set up quickly for tensile, tear, adhesion, burst, seam construction, and many other physical tests . . . with ranges from the lowest up to 1000 lbs. or 500 kgs.

LAB MEN AND PRODUCTION MEN have recognized and relied on the "sure test" by Scott for more than 60 years . . . for product development, process control, quality control, acceptance sampling, and the countless other tests that make the difference between profit and loss. If *you* want high-precision testing that is economically feasible for research or production . . . or if you're having trouble meeting industry standards . . . be sure to check your tester needs with Scott.

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- ☐ High temperature deterioration testers
- ☐ Low temperature brittleness testers
- ☐ Flexing and compression testers
- ☐ Tear and seam testers
- ☐ Adhesion and lamination testers
- ☐ Rubber and elastomer viscosity testers
- ☐ Internal bond testers

SCOTT TESTERS, INC.
120 Blackstone Street
Providence, Rhode Island

FOR FURTHER INFORMATION CIRCLE 457 ON READER SERVICE CARD

NEWS OF MEMBERS

(*Continued from p. 92*)

plied sciences of the Université Libre de Bruxelles. The insignia was presented to him during the university's 125th anniversary celebration.

A. J. Warner has been appointed manager of research and engineering, Aerovox Corp., New Bedford, Mass. Previously he was a consultant with DeBell & Richardson, Inc., Hazardville, Conn.

DEATHS . . .

Walter W. Arpe, Tucson, Ariz. (Nov. 11, 1959). Before retiring in 1950, he was assistant general manager of sales, Laclede Steel Co., St. Louis, Mo. Mr. Arpe was a member of the Society for more than 20 years.

Alfred Bellis, Morrisville, Pa. (Nov. 10, 1959). Prior to his retirement in 1949, Mr. Bellis was chief electrical engineer, John A. Roebling Sons Co., Trenton, N. J. Mr. Bellis joined the Society in 1923 and over the years was very active in committee work. He was a member of Committee A-5 on Corrosion of Iron and Steel, B-1 on Wires for Electrical Conductors, which committee elected him to Honorary Membership in 1949 for his outstanding contributions to the work of the committee, D-11 on Rubber and Rubber-Like Materials, D-14 on Adhesives, and E-8 on Nomenclature and Definitions.

R. G. Coleman, chief, materials laboratory, Massey-Ferguson, Inc., Detroit, Mich. (Apr. 7, 1959). Mr. Coleman represented his company in Society membership.

Murray Erick, consulting engineer, Murray Erick Associates, Los Angeles, Calif. (Aug. 1, 1959). Mr. Erick joined the Society in 1946.

E. B. Fields, mechanical assistant, engineering and research, Office General Manager Mechanical Dept., Atchison, Topeka & Santa Fe Railway, Chicago, Ill. (Oct. 2, 1959). Mr. Fields joined ASTM in 1948 and since that time was active in committee work. He was a member of Committees A-1 on Steel, A-2 on Wrought Iron, A-3 on Cast Iron, A-7 on Malleable-Iron Castings, and D-11 on Rubber and Rubber-Like Materials.

John Fox, London representative, Belliss & Norcom, Ltd., London, England (Oct. 19, 1959). Mr. Fox had been a member of the Society since 1950.

Forrest Ladd, vice-president, John A. Denie Sons Co., Memphis, Tenn. (recently). Mr. Ladd became a member of the Society in 1948.

P. D. Miesenhelder, research engineer, Concrete Research Staff, Association of American Railroads, Chicago, Ill. (Nov. 17, 1959). Mr. Miesenhelder held membership in the Society since 1921 and over the years actively participated in the work of Committees D-4 on Road and Paving

(*Continued on p. 96*)

DEATHS

(*Continued from p. 95*)

Materials, C-1 on Cement, and C-9 on Concrete and Concrete Aggregates.

B. P. Mulcahy, president, Fuel Research Laboratory, Inc., Indianapolis, Ind. (Aug. 31, 1959). During his 20 years of membership in the Society, Mr. Mulcahy was an active member of Committees D-3 on Gaseous Fuels and D-5 on Coal and Coke. He also served as a member of the Ohio Valley District Council.

D. Nabow, designing engineer, Duke Power Co., Charlotte, N. C. (recently). Mr. Nabow represented his company's sustaining membership in the Society.

Garnet P. Phillips, general supervisor, foundry research, manufacturing research, International Harvester Co., Chicago, Ill. (Nov. 29, 1959). Mr. Phillips was a 25-year member of the Society, and for an equal number of years actively participated in the work of Committee A-3 on Cast Iron.

S. Blake Roberts, district manager, Robert W. Hunt Co., St. Louis, Mo. (Oct. 27, 1959). Mr. Roberts joined the Society in 1943 and was on the council of the St. Louis District, having served as secretary, vice-chairman, and treasurer.

Richard E. Schmidt, architect, Schmidt, Garden & Erickson, Chicago, Ill. (Oct. 17, 1959). A 40-year member, Mr. Schmidt joined ASTM in 1915.

R. A. Stalnaker, supervisor, Physical Testing Laboratory, Robertshaw-Fulton Controls Co., Robertshaw Thermostat Div., Materials Laboratory, Youngwood, Pa. (recently). Mr. Stalnaker joined the Society in 1957.

Rees F. Tener, technologist, National Bureau of Standards, Washington, D. C. (December 25, 1959). Mr. Tener joined the Society in 1946 and since that time actively participated in the work of Committees D-13 on Textile Materials and D-11 on Rubber and Rubber-Like Materials.

Lambertus van Ouwerkerk, management director, Rontgen Technische, Dienst nv., Rotterdam, Netherlands (Oct. 25, 1959). Mr. van Ouwerkerk, a member of the Society since 1951, was a member of Committee E-7 on Nondestructive Testing.

Other Societies' Events

February 1–4—**American Society of Heating, Refrigerating, and Air-Conditioning Engineers,** Semiannual Meeting and Exposition, Baker Hotel and Memorial Auditorium, Dallas, Tex.

February 1–5—**American Institute of Electrical Engineers,** Winter Meeting, New York, N. Y.

February 1–5—**Instrument and Automation Conference and Exhibit,** Sam Houston Coliseum, Houston, Tex.

February 2–4—**Society of the Plastics Industry,** Reinforced Plastics Div., Edgewater Beach Hotel, Chicago, Ill.

February 4–6—**American Society for Metals,** Metals Conference, Fairmont Hotel, San Francisco, Calif.

February 14–18—**American Institute of Mining, Metallurgical and Petroleum Engineers,** Annual Meeting, Hotels McAlpin and Statler, New York, N. Y.

February 15–19—**National Sand and Gravel Assn. and National Ready Mixed Concrete Assn.,** Convention and Biennial Exhibit, Conrad Hilton Hotel and Coliseum, Chicago, Ill.

February 18–20—**National Society of Professional Engineers,** Winter Meeting, Broadview Hotel, Wichita, Kans.

February 21–24—**American Institute of Chemical Engineers,** Biltmore Hotel, Atlanta, Ga.

February 22–25—**Technical Association of the Pulp and Paper Industry,** Annual Meeting, Commodore Hotel, New York, N. Y.

February 29–March 4—**Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy,** Penn-Sheraton Hotel, Pittsburgh, Pa.

March 7–8—**Steel Founders' Society of America,** Annual Meeting, Drake Hotel, Chicago, Ill.

March 14–17—**American Concrete Inst.,** Annual Meeting, Commodore Hotel, New York, N. Y.

March 14–16—**American Railway Engineering Assn.,** Annual Meeting, Sherman Hotel, Chicago, Ill.

March 14–18—**National Association of Corrosion Engineers,** Annual Conference and Corrosion Show, Memorial Auditorium, Dallas, Tex.

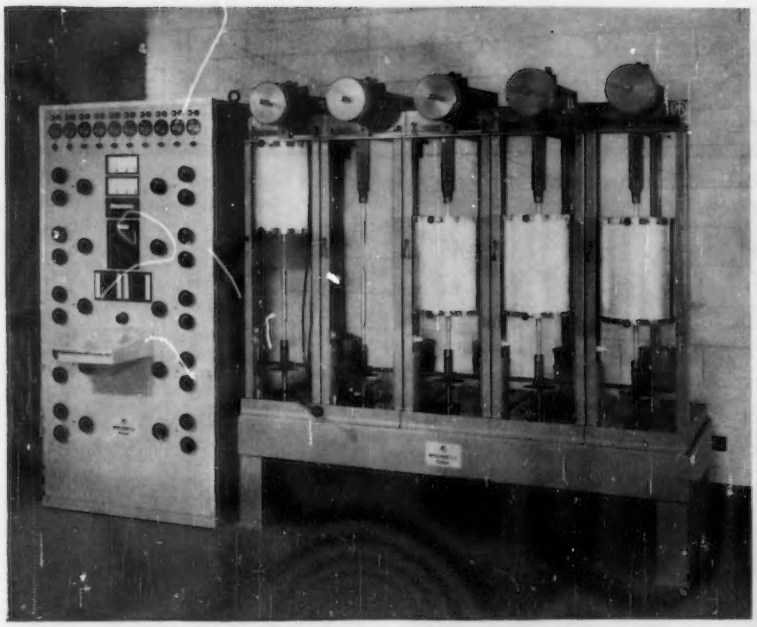
March 15–21—**3rd International Conference on Nondestructive Testing,** Tokyo, Japan.

Pallet Sizes Standardized

UNTIL NOW, the sizes of pallets, the platforms used to hold materials while they are moved about and stored, have been a matter of individual choice for each user. Thus, a confusion of pallets has streamed through our trucks, boxcars, and warehouses. With increasing mechanization of materials handling goes increased use of pallets. To promote efficiency, economy, interchangeability, and flexibility in storage, rail, truck, ship, and air transport, the American Standards Assn. has approved a new standard, ASA MH 1.1-1959, which provides a series of standard pallet sizes—eight rectangular and three square.

Criteria used for setting the standard sizes (boxcar and truck-trailer dimensions) are shown in the standard. It is hoped that the eight sizes will replace the many hundreds of sizes now in use in this country.

Sponsors of the standard are the Society of Packaging and Handling Engineers and The American Society of Mechanical Engineers. The standard is published by ASME. This is the first step in the establishment of a complete pallet standard that will include additional definitions, materials, and performance testing.



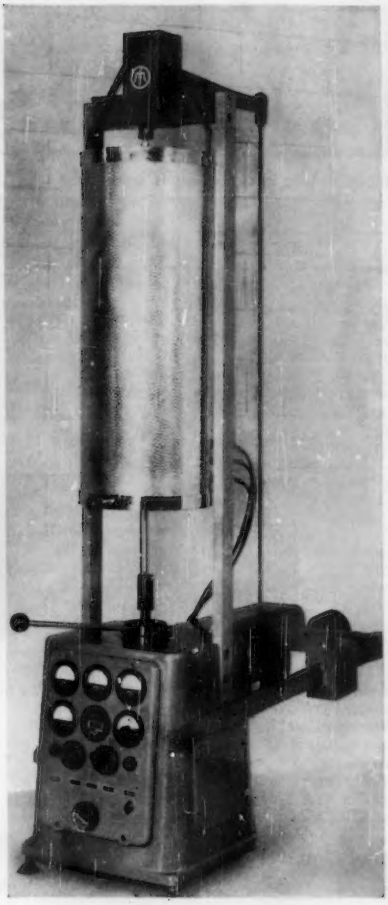
Above: The control cabinet shown has regulating and measuring equipment suitable for 10 furnaces. The furnaces are independent from one another. Equipment of this type is desirable for research and original explorations.

MOHR & FEDERHAFF

Creep Strain Testers

SINLGE SAMPLE OR MULTIPLE SAMPLE

Creep testing has in many instances progressed from an experimental to a routine basis in the past few years. The physical properties of a steel which is to be used at normal temperatures can be determined by a simple test, because the properties of steels do not change with time at ordinary temperatures. However, the designers now want materials which will endure high temperatures under load for long time periods. Such materials are needed to obtain greater efficiency in modern and future engines, turbines and other machinery. We have the problem of testing many possible materials at many possible loads at many different temperatures over many different time periods. The question arises—Is it possible to test for a short period, say 48 hours and extrapolate the results for longer times? Unfortunately, in most cases the answer is no, if temperatures over about 400° C. (720° F.) are under consideration. Test periods of 1,000 to 10,000 hours are common and tests up to 100,000 hours (over 10 years) are being carried out.



Ten samples strung end to end are accommodated by this tester. Its low cost per specimen makes large volume routine testing possible.

It is obvious that a large number of single sample testers would be required for a long term test program on even a few steels.

Mohr & Federhaff, in cooperation with some of the most advanced creep test laboratories in Europe, have arrived at the following solution: A few individual or battery type testers for individual samples should be used for research and experimental work with the balance of the long term testing being handled by multiple testers accommodating 10 samples fastened end to end in one furnace and loading system. This has made large scale testing possible.

We believe an examination of the problem indicates that the combination of a few single unit creep testers with several multiple testers affords the most satisfactory means of obtaining voluminous creep data.

NEWS NOTES ON
Laboratory Supplies and Testing Equipment

Note. This information is based on literature and statements from apparatus manufacturers and laboratory supply houses. The Society is not responsible for statements advanced in this publication.

LABORATORY ITEMS

Profile Monitor—The profile monitor model 201 provides an accurate, visual display of any phenomena measurable by an electrical output. Typically monitored are temperature, pressure, strain, and velocity. With accommodations for as many as 90 inputs, the profile monitor can display one of these phenomena, or any combination having comparable electrical outputs.
Advanced Technology Laboratories Div. of American-Standard 3272

Analytical Balance—A completely redesigned model of the "right-a-weigh" one-pan analytical balance is announced. The new unit incorporates the same basic principles of operation, using the substitution weighing and having built-in weights and projection reading.
Wm. Ainsworth & Sons, Inc. 3273

Lubricant Tester—A new lubricant testing machine designed for environmental research has been announced. The machine, known as the model LFW-3, can be adapted to high temperatures, with oscillatory or rotational motion, over a wide range of velocities and loads.
The Alpha-Molykote Corp. 3274

Electrical Thermometer—The model T-1 precision electrical thermometer is a compact and simple-to-use instrument designed primarily for quick determination of surface and immersion temperatures in either laboratory or production line applications.
Ameresco, Inc. 3275

Microphotometer—A new projection comparator-microphotometer for spectrographic analysis is announced. The unit features stability, versatility, and operator convenience.
Applied Research Laboratories, Inc. 3276

Leakage Current Tester—The new model 8515 insulation life tester provides extended insulation current leakage tests for electrical and electronic equipment, materials, components, and completed installations. This instrument will make sequential tests of up to 50 components or circuits for periods to 12 hr without manual adjustments or attention.
Associated Research, Inc. 3277

Strain Gage—Representing a new concept in strain gage temperature compensation, a unique, dual-element, SR-4 foil gage has been announced. This new strain gage is universally temperature compensated—that is, it effectively minimizes the apparent strain caused by temperature change when bonded to any one of a broad variety of materials.
Baldwin-Lima-Hamilton Corp. 3278

High-Speed Cameras—The Waddell 16-mm high-speed camera was specifically developed to be used where high-speed motion picture recording is necessary. It has a speed range of from 3 to 10,000 pictures per sec, depending on the camera model and motor combination. It will accept the normal 400-ft magazine, and is driven by either a permanent-magnet 26-v d-c or a 115-v a-c/d-c motor, depending on the model.
Camera Equipment Co. 3279

Spring Tester—This new interchangeable manual spring tester tests both compression and extension springs with a high degree of accuracy. Three different sets of springs are provided, which can easily and quickly be changed to vary the capacity of the tester from 0.01 to 25 lb.
John Chatillon & Sons 3280

Purge Meter—A new, one-piece, series CM purge meter capable of indicating small gas or liquid flows where extremely high accuracy is not required is introduced. The new unit is designed for all

general purging applications in which only a positive flow indication as well as reproducibility of small flow conditions is of prime importance.
C-Mar Corp. 3281

Environmental Chambers—Temperature test chambers offering a wide variety of performance characteristics are now available for rack-mounted installation. Model 6545R has a test volume of 10 by 7 by 7 in., occupies 10½ in. in a 19-in. rack, and is thermostatically controlled to within ±2 F throughout the −100 to 500 F range. Similar in dimensions, model 1060R offers temperature stability to ±0.2 F, accomplished by a thermocouple detector unit in conjunction with a high-precision meter-relay circuit, as well as automatic hot-cold cycling controlled by an auxiliary timer.
Delta Design, Inc. 3282

Safety Lift—The Lab-Lift raises or lowers a load of several hundred pounds on its 9½-in.-square top plate through a vertical distance of 8 in. (that is, to 13 in. from the at-rest height of 5 in.).
Fisher Scientific Co. 3283

Pressure Gage—A new series of electrical instruments for accurate determination of differential pressure of air and other gases is announced. The most sensitive of this new series of instruments has a full-scale range from 0 to 0.01 in. of water and detects pressure differences as small as 0.0001 in. Other models have full-scale ranges from 0 to 0.03, 0.1, 1.0, 3, 10, 20, 50, and 100 in.
Hastings-Raydist, Inc. 3284

Oscilloscope Camera—A convenient, easy-to-use oscilloscope camera which records full-size oscilloscope patterns without distortion on Polaroid® Land film is now available. The camera, model 196A, uses a standard camera bellows to eliminate light leakage.
Hewlett-Packard Co. 3285

Arc Resistance Tester—Model ART-2 arc resistance tester is used to measure resistance of insulating materials to high-voltage arcs. ART-2 is supplied in conformance with ASTM Specifications D 495–56 T and Federal Specifications LP-406, Method 4011.2. The Model ART-2 has arc-current steps of: 10/8, 10/4, 10/2, 10, 20, 30, 40, 60, 80, and 100 ma, and a built-in timer.
Industrial Instruments, Inc. 3286

Vibration Test Machine—A new vibration testing machine, type 400-U-SP, has been introduced. It is designed specifically for industrial production lines as a quality control unit for vibrating assembled products as they come from the production line to determine errors in assembly.
L. A. B. Corp. 3287

Magnetic Amplifier—A new magnetic amplifier designed for current-proportioning control instruments in a variety of applications in glass, ceramics, and metal heat-treating operations has been introduced. The device can be used with any proportioning controller having an output span between 0.3 and 20 ma to provide a stepless, contactless means of electric furnace control.
Minneapolis-Honeywell Regulator Co. 3288

Test Set—Features dielectric testing up to 5 kv rms; any number of test positions to order; voltage continuously adjustable up to 5 kv rms; test duration or dwell time

(*Continued on p. 100*)

LABORATORY ITEMS

(*Continued from p. 99*)

adjustable from 1 to 120 sec; and maximum short-circuit current limited to 5 ma.
Peschel Electronics, Inc. 3289

Laboratory Cart—This new laboratory cart is designed to give portable storage space for all accessories, attachments, and apparatus. Rim on cart top keeps things from sliding off. Over-all dimensions: 29 by 20 by 33 in.
Planchets 3290

Buret—A constant-rate buret, the precise constant delivery device for titration with laboratory recorders has been developed. This instrument consists of ground Pyrex brand glass solution barrels and plungers, operating on a simple displacement principle with the plunger driven at a constant rate by a synchronous motor.
E. H. Sargent & Co. 3291

Dial Indicators—Two indicator models are now available. One features direct readings in 0.00005 in. with a full range of dial of 0.004 in. and 20-0-20 graduations. The other model has direct readings in 0.0005 in., 0.016 in. full dial range, and 8-0-8 graduations. Both models have a cam-lock adjustment for zeroing.
Scherr-Tumico 3292

Hardness Tester—A new micro hardness tester, with a vertical capacity of 8 in. has been announced. The Kentron micro hardness tester, model AK-8, applies dead weight loads from 1 to 1000 g. (Additional weights for applying heavier loads up to 10,000 g can be furnished as optional equipment.)
Torsion Balance Co. 3293

Burner—A portable bunsen burner, operating on propane gas, is now being offered. Ideal for laboratories, classrooms, and field laboratories, the burner requires no hose connections or gas outlets. It is especially convenient for schools not equipped with gas.
Turner Corp. 3294

Thermometers—Insertion type, vapor actuated dial thermometers for duct installations feature ease of reading and dependable accuracy throughout the entire working range, a progressively graduated scale for use in the upper two-thirds of the range. Various sizes available and ranges from −40/65 F to 100/350 F.
Weksler Instruments Corp. 3295

CATALOGS & LITERATURE

Infrared Research—The fourth in a series of infrared *Progress Reports* has been published. *Report No. 4* describes three types of glass which have been specifically developed for refractive systems.
Bausch & Lomb Optical Co. 6167

Torque Meter—A complete line of torquemeters and indicators—with individual models designed to satisfy specific industrial torque measuring requirements—in standard ranges from 1 in.-oz full scale through 30,000 in.-lb full scale and high-speed capability to 50,000 rpm are illustrated and described in two bulletins recently issued.
B & F Instruments, Inc. 6168

Materials Technology—A new quarterly publication dealing with materials for severe environments such as corrosion, chemical attack, high-temperature, and abrasion has been announced. Free subscription available.
Carborundum Co. 6169

Metallograph—A folder describing the Vickers Mark IV metallograph and attachments is now available.
Cooke, Troughton & Simms, Inc. 6170

Infra-Ray Gage—A new descriptive folder *No. 13-203-A* details equipment and operating principles of a new noncontact, radiation-operated gage which measures and records the width of hot strip traveling at speeds as fast as 2000 ft per min.
Daystrom, Inc. 6171

Dissolved Oxygen Analyzer—A new oxygen analyzer utilizing a unique property of thallium which is extremely reactive with traces of oxygen and at the same time inert to water is available. The system consists of a mixed bed demineralizer cartridge and a packed column of pure thallium. The equipment is usable down to several parts per billion dissolved oxygen, described in *Data Sheet C959*.
Industrial Instruments, Inc. 6172

Electronic Instruments—The Keithley 1960 catalog describes and illustrates instruments for electronic, biological, and chemical measurement and control. Specifications and performance data are included for the complete line of instruments, including the newest additions.
Keithley Instruments, Inc. 6173

Glass Catalog—Sixty-seven new laboratory glassware items of interest to the scientific laboratory profession are listed in the 40-page supplement *SP-57*. These new listings cover styles, shapes, sizes, conversions to hard glass, and new products now available in the Kimble line.
Kimble Glass Co. 6174

Optical Systems—Optical systems and film handling devices research and development engineering is described in a new 16-page booklet now being offered. The booklet illustrates 25 solutions to unique photo-optical problems.
Mast Development Co., Inc. 6175

Magnetic Particle Inspection—A new 36-page booklet describing wet magnetic particle inspection using Immunol 438 in water as the vehicle for oil-soluble and water-soluble inspection pastes instead of kerosine or solvents, with accruing advantages of better definition of flaw, substantial cost reduction, cleaning and rust-proofing; and the elimination of fire hazard, skin infection, inhalation hazards, odor, and foam has been announced.
Harry Miller Corp. 6176

Radiation Gage—New two-page *Bulletin ASR-3* gives specification data and performance advantages of the Ohmart density measurement and control gage for use on pipes up to 3 in. in diameter. Gage is bolted into slurry or liquid line and makes continuous measurements of the specific gravity of the material flowing through the pipe.
The Ohmart Corp. 6177

X-Ray Diffraction—A new catalog index listing items of interest in X-ray diffraction and spectroscopy equipment is available. Seventy-three items are listed.
Radio Corporation of America 6178

Plastic Apparatus—A 24-page *Catalog No. H459* describes a full line of plastic laboratory equipment and apparatus.
Rascher & Betzold, Inc. 6179

Federal Government Standards Index Changes

THE FEDERAL Supply Service of the General Services Administration is charged with the responsibility for establishing specifications to be used by the Federal Government for Procurement of materials and supplies. The GSA issues an annual Index of Initiation of Federal Specifications Projects, and monthly supplements.

The items listed below appeared in Supplement No. 8 for the month of November 1959.

INITIATIONS

Title	Type of Action	Symbol or Number	FSC Class	Assigned Agency & Preparing Activity
Aluminum Alloy Forgings, Heat Treated	Am. 2	QQ-A-367d	....	DOD-Navy-Ord
Aluminum Alloy Rivet and Cold Heading Wire and Rods	New	....	9525	DOD-Navy-Aer
Boxes, Wood, Nailed and Lock-Corner	Rev.	PPP-B-621a	8115	DOD-Army-QMC
Boxes, Wood, Wirebound	Rev.	PPP-B-585a	8115	DOD-Army-QMC
Cloth, Cotton, Duck, Unbleached Plied Yarns (Army & Numbered)	Rev.	CCC-C-419a	8305	DOD-Army-QMC
Cloth, Cotton, Jean (Unbleached)	Rev.	CCC-C-444a	8305	DOD-Amy-QMC
Cloth, Cotton, Sheeting	Rev.	CCC-C-430a	8305	DOD-Army-QMC
Dibutyl-Phthalate Plasticizer (For Use in Organic Coatings)	Rev.	TT-D-301b	6810	GSA-FSS
Hose, Rubber, Water (Yarn Reinforced)	Am. 1	ZZ-H-601a	4720	COM-NBS
Paint, Oil, Interior, Flat, White and Tints	Rev.	TT-P-51e	8010	DOD-Army-CE
Paperboard, Wrapping, Cushioning	Int. Am. 1 & Am. 2	PPP-P-291a	8135	GSA-FSS
Pipe Fittings; Malleable Iron, Wrought Iron, and Steel (Screwed), 150-lb.	Am. 1	WW-P-521d	4720	DOD-USAF

Printing and Stationery Paper, Packaging and Packing for Domestic and Overseas Shipment	Int. Am. 1	PPP-P-25	7530	GSA-FSS
Tape, Textile, Cotton, General Purpose (Gray, Bleached, or Dyed)...	Rev.	DDD-T-86c	8315	DOD-Army-QMC
Thinner, Paint, Volatile Mineral Spirits (Petroleum Spirits).....	Rev.	TT-T-291b	8010	DOD-Navy-Ships

PROMULGATIONS

Title	Type of Action	Symbol or Number
Stitches, Seams, and Stitchings.....	New	Fed. Std. No. 751
Bottle, Stopper, Narrow Mouth, Round.....	New	DD-B-597
Brazing Alloys, Aluminum and Magnesium, Filler Metal (Superseding QQ-B-00655a (Army-Ord) (in part)).....	New	QQ-B-655b
Feathers, Land Fowl (Crushed) (Superseding C-F-00158(GSA-FSS) & C-F-151a (in part)).....	New	C-F-158a
Feathers, Waterfowl and Down, Waterfowl (Superseding C-F-00160(GSA-FSS) & C-F-151a (in part))	New	C-F-160a
Isobutyl Acetate (For Use in Organic Coatings)..	New	TT-I-710
Lacquer, Multi-color, Aqueous, Dispersion Type (For Spray Application).....	New	TT-L-45b
Methyl Isobutyl Ketone (For Use in Organic Coatings (Superseding TT-M-00268a(GSA-FSS) & TT-M-268)	Rev	TT-M-268b

INDEX TO ADVERTISERS

LOOK

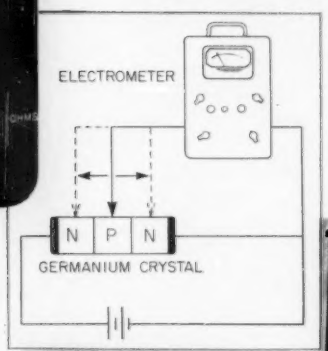
what one instrument will do!

MEASURES

VOLTAGES from 0.5 mv to 10v

CURRENTS from 0.005 $\mu\mu$a to 1 ma

RESISTANCES from 0.3 MΩ to 500 MMΩ



and Also Serves as a D-C Amplifier to Drive Oscilloscopes and Recorders

TYPE 1230-A D-C AMPLIFIER AND ELECTROMETER $440

- True direct-coupled amplifier design — no choppers, vibrators, or reeds to give mechanical trouble or get out of adjustment.
- High input resistance: 100 mega-megohms — does not load down sensitive circuits. Input resistance can also be set by switch to other values from 10^4 to 10^{11} ohms.
- Reliable operation even under conditions of high humidity — insured by silicone treatment of the electrometer tube's input and use of teflon insulation throughout input circuit.
- Electrometer stage protected against physical shock, ambient light effects, dust and random electrostatic fields.
- Guard point provided for three-terminal or ungrounded resistance measurements.
- High instrument stability — careful selection and aging of components, and shock mounting insure maximum instrument stability.
- Switch position provided for checking instrument's high-value internal resistance standards in terms of its lower-valued wire-wound standards.
- Constant low voltage across unknown (9.1v) — no need for voltage coefficient corrections when making high resistance measurements.
- Output for recorders

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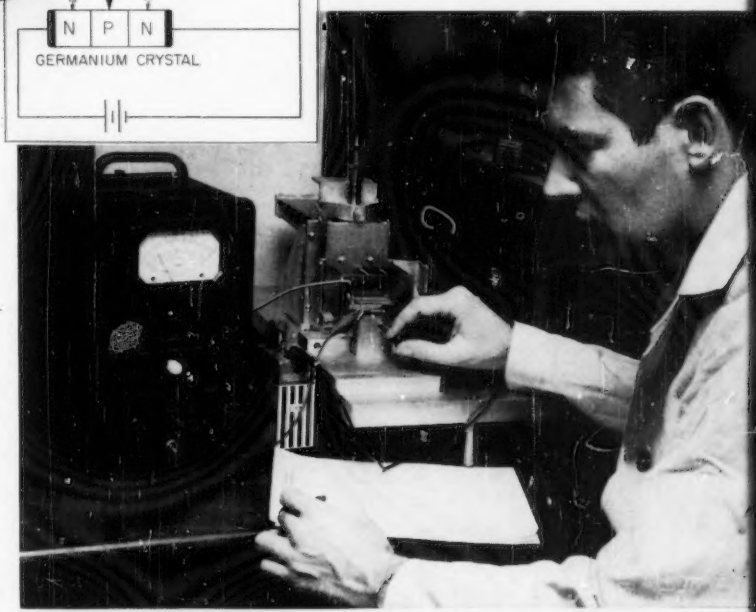

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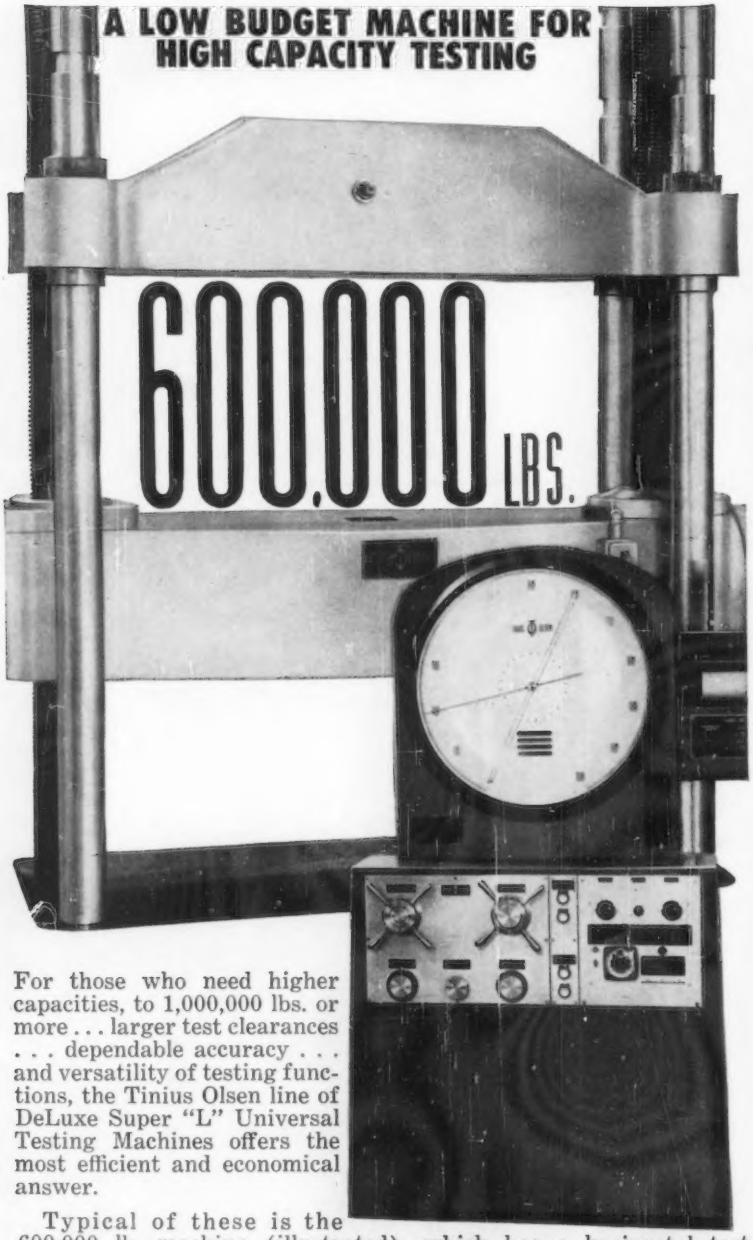

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